Report No. CG-D-02-95

# EVALUATION OF INNOVATIVE VESSEL INSPECTION TECHNIQUES

## Phase I - Hand Held and Basic Technology

Michael J. Goodwin
Edward F. McClave

MAR, Incorporated
6110 Executive Boulevard, Suite 410
Rockville, MD 20852



FINAL REPORT
NOVEMBER 1994



Prepared for:

U.S. Coast Guard
Research and Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

and

U.S. Department of Transportation
United States Coast Guard
Office of Engineering, Logistics, and Development
Washington, DC 20593-0001

# NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

The contents of this report reflect the views of the Coast Guard Research & Development Center. This report does not constitute a standard, specification, or regulation.


D. L. Motherway
Technical Director, Acting
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

Technical Report Documentation Page

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| CG-D-02-95 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| **EVALUATION OF INNOVATIVE VESSEL INSPECTION TECHNIQUES**<br>**Phase I - Hand Held and Basic Technology** | November 1994 |
| | 6. Performing Organization Code |
| 7. Author(s) | 8. Performing Organization Report No. |
| Goodwin, Michael and McClave, Edward | R&DC 29/94 |
| 9. Performing Organization Name and Address | 10. Work Unit No. (TRAIS) |
| MAR, Inc.<br>6110 Executive Boulevard, Suite 410<br>Rockville, MD 20852 | 11. Contract or Grant No.<br>DTCG39-91-D-E33A21 |
| | 13. Type of Report and Period Covered |
| 12. Sponsoring Agency Name and Address | Final Report<br>June 1993 to November 1994 |
| U.S. Department of Transportation<br>United States Coast Guard<br>Research and Development Center<br>Groton, CT 06340 | 14. Sponsoring Agency Code |

15. Supplementary Notes

16. Abstract

**This report provides the results of the first phase of the testing effort to evaluate marine inspection equipment and techniques for use by Coast Guard marine inspectors. A previous report identified many potentially useful techniques that could enhance inspections both by providing better information and by speeding up inspections. The current study evaluated some of the equipment required, primarily lighting equipment, in greater depth. More advanced techniques, including some under development and not commercially available, are intended to be reported on in a future report.**

**The technology categories covered include: head-mounted lights, hand-held lights, deck-based lights, telescopic aids, night vision systems, and hand-held video cameras. Polarized filter contrast enhancement, deck-based video cameras, and remotely operated video cameras were also considered but were not evaluated in the field. Candidate equipment were identified based on manufacturers literature for each of the categories above. These were ranked based on criteria selected by the contractor as important in the inspection process. The Coast Guard chose equipment based on this ranking and purchased samples for field testing.**

**Equipment was tested at five locations by marine inspectors under actual local inspection conditions. Their observations and comments are summarized in this report. Also, a select group of lights were evaluated in the light tunnel at the Coast Guard Research and Development Center to determine actual intensity versus time characteristics and the service life of batteries.**

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Marine Inspection<br>Inspection Lights<br>Telescopic Aids<br>Night Vision Equipment<br>Light tests | Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161 |

| 19. Security Classif. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 107 | |

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized

# METRIC CONVERSION FACTORS

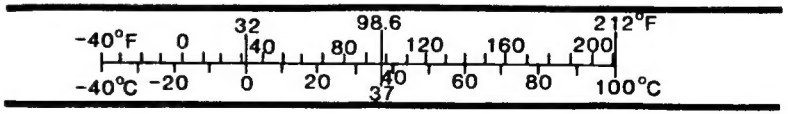
## Approximate Conversions to Metric Measures

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | * 2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (WEIGHT)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (EXACT)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly).


## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (WEIGHT)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 0.125 | cups | c |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (EXACT)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



## TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF FIGURES (continued)



## LIST OF TABLES

# 1 INTRODUCTION

The purpose of this project was to identify, rank, test, and evaluate equipment which could improve the efficiency and the effectiveness of Coast Guard structural inspections of merchant vessels. The project comprised five principal phases. In the first phase, applicable equipment was identified and, based upon specifications and other information from manufacturers, was rated and ranked by performance and performance/cost criteria. Recommendations were made for the purchase of equipment for field testing. The report for this phase of the project is included as Appendix A of this report. This phase was also performed by the MAR, Inc.(MAR) The cost of the equipment contained in Appendix A does not reflect government cost to purchase in all cases.

The second phase involved acquisition of equipment. Based on the recommendations made by MAR, Inc., during the first phase, and subject to the budgetary limitations of the project, a large number of items were purchased for testing. Initial testing was done to weed out equipment which was clearly not useful. This phase was performed by Coast Guard Research and Development Center (R&D Center) personnel.

During the the third phase, equipment was tested by working Coast Guard inspectors in actual inspection environments. MAR and R&D Center personnel were present at these tests to assist inspectors and to record their evaluations of the equipment. In some cases, equipment was left with inspectors at the conclusion of the field tests for further long-term evaluation.

After the field tests concluded, MAR and R&D Center personnel tested some of the lights in the R&D Center light tunnel. Tests were performed to determine actual service life, brightness, and beam width. The results of these tests will be documented in a future report.

The fifth and final phase was the reporting of the results of the field and laboratory tests. This phase included re-ranking and re-prioritization of that equipment which field testing showed was potentially useful to inspectors. This report covers this final phase.

## 1.1 The Inspection Process

The Coast Guard inspects merchant vessels to verify that they are seaworthy, competently manned, and that they present no dangers to passengers or crew, to other vessels, or to the environment. The most demanding and difficult aspect of merchant vessel inspection is that of conducting structural inspections on deep-draft vessels, particularly tank vessels.

In conducting a structural inspection of a large vessel, Coast Guard inspectors must ascertain the vessel's condition in a fairly short time, while working primarily in very large, poorly lit spaces, and with minimal opportunities for close-up physical access to important

structural components. A typical inspection of a large vessel is conducted by one or two inspectors and takes 2 to 6 inspector-days of on-board inspection time.

The inspection process begins long before the actual inspection. Using vessel information and records of previous inspections obtained from the Marine Safety Information System (MSIS), the inspectors familiarize themselves with the vessel. If available, the full inspection records of previous inspections (filled-in inspection books, inspection diaries, and other information), may be consulted, and the inspector who conducted the previous inspection of that vessel may be contacted.

Certain vessels, because of their type, their individual or class history, the cargo they carry, or the route they sail, may have particular structural components which are known to be prone to failure, and which may require more detailed inspection. Some of these vessels are subject to the Critical Area Inspection Plan (CAIP) requirements.

Most inspections of large U.S. flag vessels are conducted while the vessel is in a shipyard (either in the U.S. or overseas) for scheduled maintenance and repairs. Prior to such shipyard periods, vessels are generally surveyed by commercial surveyors working for the owner. In addition, vessels are surveyed regularly by their classification societies. Each inspection office is responsible for inspection of vessels in its area, regardless of the vessel's port of registry. Some larger offices also conduct inspections of U.S. vessels in foreign ports.

Foreign tank and freight vessels are also inspected, but in considerably less detail than U.S. vessels. These inspections are generally conducted when a vessel first calls at a U.S. port from an overseas location. The purpose of foreign vessel inspections is to verify the effectiveness of the vessel's flag state inspection and classification society surveys, and to ensure that the vessel complies with basic standards of seaworthiness, structural integrity, safety, and environmental compliance.

The responsibility of Coast Guard inspectors when conducting structural inspections is not to serve as surveyors for the vessel's owner, but to verify the vessel's seaworthiness. The identification and repair of structural problems is primarily the responsibility of the owner, and the purpose of the Coast Guard inspection is to ensure that this responsibility is carried out properly. The findings of the Coast Guard inspectors are not intended to be the primary means by which the owner determines the nature and extent of a vessel's structural problems. Accordingly, inspectors expect that the vessel's master or chief engineer, or the port engineer for the owner advise them before the inspection begins about any structural problems which have appeared since the vessel's last Coast Guard inspection, and about repairs proposed, underway, or completed to correct these problems. The inspectors may also consult commercial surveyors, classification society surveyors, and shipyard personnel who have surveyed or worked on the vessel recently in order to determine the details of a vessel's condition and of structural repair work in progress.

During the actual inspection, the inspector or inspectors closely inspect all of the problem areas of which they have been previously advised to assess the severity of the problem and to ensure that the proper repairs are made. These areas are often well illuminated and may have staging or other means of access provided for the workers doing the repairs.

Coast Guard inspectors also conduct an overall inspection of the entire vessel to ensure that there are no structural problems which the owner has failed to identify and address. This overall inspection always covers all accessible spaces on the vessel. The thoroughness with which inspectors conduct this overall screening part of the inspection depends somewhat upon the overall state of maintenance of the vessel and upon the past performance of the owner and crew in providing accurate and complete information about the vessel's structural condition to the Coast Guard.

During the overall phase of the inspection, the inspectors must scan the entire internal structure of the vessel in a limited time. Areas which are not undergoing repair are poorly illuminated and there are often no provisions for close-up access to important structural components such as the underdeck structure. If the inspectors find an indication of a structural problem, they may require the owner to provide better lighting and means of close-up access, such as staging, and they may require the owner to have non-destructive testing (NDT) performed. Fixed lighting equipment, enhanced means of access, and NDT are provided by contractors or shipyards at the vessel owner's expense. Inspectors may return to a vessel to observe important repair work or tests on repaired areas, and they generally return to the vessel after work is completed to verify that all of the repairs to previously identified structural problems have been performed properly.

## 1.2 The Need for Improved Equipment

It is during the overall phase of the inspection that improved inspection equipment has the greatest potential for increasing the efficiency of the inspectors. Much of this inspection is conducted without the possibility for up-close access to the components being inspected. The quality of the inspectors' hand-carried lights, in particular, is very important. Inspectors are limited to equipment which they can carry easily while climbing in very large spaces such as cargo tanks and while crawling through tight spaces such as double-hulls or ballast tanks.

# 2 SCOPE

The primary focus of this project was to identify and evaluate portable equipment which inspectors can carry with them. Because inspectors must carry most of their equipment on their persons in difficult locations, the size and weight of the equipment is often as important as its effectiveness. This type of equipment is generally the property either of the inspection office or of the individual inspectors, both of which have limited budgets for equipment purchases, and therefore the cost is a significant factor.

A secondary focus of the project was to identify, and in a few cases, to test, equipment which is too large to be carried easily by inspectors and which is more likely to be owned and used by a vessel's owner, by a shipyard, or by a contractor performing specialized inspection services.

## 2.1 Initial Identification and Ranking of Equipment

During the first phase of this project, the contractor used manufacturers' literature and direct communications with equipment manufacturers to develop a list of potentially useful inspection equipment or technologies in ten categories. These categories were:

1. Head-mounted lights
2. Hand-held lights, including:
    - Flashlights
    - Hand lanterns
    - Self-contained spot/floodlights
    - Battery-pack powered spot/floodlights
3. Deck-based lighting
4. Telescopic aids
5. Night-vision equipment
6. Polarized filter contrast enhancement
7. Deck-based video cameras
8. Hand-held video cameras
9. Remotely operated video cameras
10. Portable gas-monitoring equipment

A scoring system was developed for each of these categories to allow the equipment to be ranked by its expected effectiveness and by its expected effectiveness-to-cost ratio. The contractor prepared a preliminary report containing the specifications of the equipment identified, the rankings, textual descriptions of each piece of equipment, and recommendations for purchase priorities. The techniques used for ranking equipment are described in Section 3 of this report, and the preliminary report containing the specifications, rankings and descriptions is included as Appendix A.

Telescopic aids include binoculars, scopes, and monoculars which provide a magnified image but do not provide additional illumination. Night-vision equipment gathers light and amplifies it before displaying the image on a small screen. The image with most night-vision equipment is green. Polarized filter contrast enhancement emphasizes the differences in reflected light angle to show discontinuities in a surface that may look smooth under ordinary light. One hand-held video camera was reviewed briefly in this series of tests. Future tests will look at remotely operated video cameras and those hung in a tank through a deck opening. A limited review of the usefulness of equipment to warn the inspector of hazardous gases was conducted during the series of tests reported.

The emphasis of this project has been lighting equipment, and a large number of hand-held lights were tested. Since different types of hand-held lights have different uses, hand-held lights have been further divided into four subcategories:

Flashlights, which can be carried in one hand and which generally can be carried in a pocket of the user's coveralls.

Hand Lanterns, which are hand-carried, one-hand devices, but which are too large to be carried in a pocket. These would normally be carried by an inspector in place of a flashlight, when higher intensity or longer battery life than that offered by a flashlight would be beneficial.

Portable flood/spotlights, which are large lights, with their batteries in the body of the light itself, which are too large or heavy to be carried continuously during a long inspection. These would normally be carried in addition to an inspector's normal flashlight when inspecting a large space, and would possibly be used in conjunction with a telescopic device. Two inspectors working together would probably carry only one such light. An inspector carrying one of these large lights might carry a somewhat smaller flashlight than would be carried without the large light.

Battery-pack powered lights, in which the power is provided to the light through a cord from a remote battery pack. In most cases, a variety of standard 12V NiCad or lead-acid rechargeable battery packs are available, most of which are intended to be belt-mounted. These lights have similar intensities to portable spot-floodlights, but are more easily carried, since the batery weight does not need to be supported by the inspector's hands. These lights would normally be carried continuously during an inspection, and the inspector using them might carry only a small flashlight or an escape light in addition.

Among flashlights, there are additional functional subdivisions: Standard flashlights of the type an inspector would routinely carry on an inspection of a tankship cargo space; smaller, lighter flashlights, which an inspector might use instead of the standard flashlight when inspecting a tight space such as a ballast tank or a double-hull; and escape lights, which are small lights which can be carried unobtrusively in a pocket for use in case the

inspector's hand-carried flashlight fails. There is a certain amount of overlap in these subdivisions, and with head-mounted lights also. For example, one light which many inspectors considered to be a good escape light was also usable as a tight-space inspection light. And a head-mounted light can also serve as an escape light in the event of a loss or failure of the normal flashlight.

## 2.2 Purchase of Equipment

Based upon the recommendations contained in the preliminary specification and ranking report, and limited by the constraints of the project budget, the R&D Center purchased equipment for hands-on evaluation and for use in field tests. The equipment purchased is listed in Appendix B.

## 2.3 Initial Evaluation

R&D Center personnel tested most of the purchased equipment briefly before the field tests in order to weed out defective or ineffective units. The decisions about what equipment would be brought on the first field test were based upon this preliminary screening.

## 2.4 Field Tests

Four field tests were conducted in which contractor and R&D Center personnel participated. In addition, a visit was made to the New York inspection office to familiarize inspectors with equipment which they would later evaluate under long-term use. Virtually all of the equipment which showed promise was used in the first test. The equipment used for each of the subsequent field tests was selected jointly by MAR and R&D Center personnel based on the types of vessels to be visited, the expected length of the test, the number of inspectors expected to participate, and on the performance of devices up to that point. In most cases, some equipment was left with the participating inspectors for longer-term evaluation by them or by other inspectors in the same office. Trip reports were submitted by MAR, Inc., after each of the tests, and these are included in Appendix C of this report. A few questionnaires were filled out by participants in the field tests immediately after the tests, these were collected by the COTR at the time.

## 2.5 Laboratory Light Tests

A selected group of lights that were preferred by inspectors for various reasons were tested in the R&D Center light tunnel. This is a long, dark room without windows that is instrumented to permit very accurate light measurements. The diameter of the spot portion of each light's beam was measured on a panel set 10 feet from the light (10 meters in the case of larger lights). The light intensity at the center and at each quadrant of the spot was measured every 15 minutes. The initial intensity, the time required for the light to drop to half the initial intensity, and the time for the light to burnout were determined. The results of these tests are given in Section 6 of this report.

## 2.6 Analysis of Results

All of the devices which performed effectively during the field tests, and others which were not effective, but which serve to point out desirable or undesirable design features or performance characteristics, are included in the analysis of the test results. The reported results are based on feedback obtained from inspectors during the tests, on questionnaires returned by inspectors who continued to use equipment after the field tests, and on the personal observations of MAR and R&D Center personnel during the field and laboratory tests.

# 3 IDENTIFICATION, PURCHASE, AND INITIAL TESTING OF EQUIPMENT

Based upon manufacturer's literature and upon other information provided by manufacturers, as many commercially available items as possible were identified in each of the ten categories listed in Section 2.1. In a few categories (polarized-filter contrast enhancement equipment, and deck-based and remote video) the technology was either proprietary, and offered by only one company, or was promising but still developmental, with no off-the-shelf systems currently available which could be tested in the marine inspection environment.

In those categories where at least several pieces of equipment were available, both performance and cost rating procedures were established. The performance rating system awarded points for desirable characteristics, such as high light intensity, long battery life, small size, light weight, etc., so the devices expected to perform the best received the most points. The cost rating system awarded points based on cost, with the most expensive devices receiving the most points. The performance ratings were divided by the cost ratings to produce a performance/cost ratio.

Equipment was ranked in order of decreasing performance rating and, separately, in order of decreasing performance/cost ratio.

In several of the equipment categories listed in section 2.1, no equipment was purchased or otherwise made available for field testing, either because of high costs or because of the unavailability of suitable equipment. These categories were deck-based lighting, polarized filter contrast enhancement, deck-based video cameras, and remotely operated video cameras. In the category of hand-held video cameras, only one was purchased, and the circumstances of the field tests did not allow it to be evaluated conclusively by inspectors.

## 3.1 Deck-Based Lighting

The deck-based lighting equipment which was originally identified as potentially useful comprised theatre-type fixed spotlights. These are large and heavy, they require considerable time and effort to set up and move, they have significant external power requirements, and both the purchase and rental costs are high. No deck-based lights were tested in the field.

## 3.2 Polarized-Filter Contrast Enhancement

Polarized-filter contrast enhancement equipment is a proprietary technology of one company. The portable version of this equipment is available for rental, but costs are high and trained technicians are required to operate it. This equipment is primarily designed for scanning flat surfaces, and there are few internal situations in tankships and barges in which

it would be usable. Therefore, polarized-filter contrast enhancement equipment was not tested.

### 3.3 Deck-Based Video Cameras

Deck-based video systems suitable for tankship inspection are presently still in the developmental stage, and there are no off-the-shelf systems presently available for purchase or rental. However, there are two present users of proprietary custom-developed deck-based video systems for tankship inspection, and their services, based on the use of this technology, are available commercially. The commercial marine surveying firm Ronald Nisbet Associates in Portland, OR has a custom-built color video system which they use in surveys of the internal structure of tankship cargo spaces. This system uses a color camera/light unit with remotely operated pan and zoom, which is lowered through a deck opening. The image is viewed on deck by trained operators, and can be recorded in color if desired. Still images can be extracted from the videotape records. Nisbet calls their technology "Remote View" and there is presently only one system.

Another video inspection system, similar to the Nisbet system, has been developed jointly by Northeast Technical Services (NETS) of Cleveland, Ohio, and British Petroleum (BP), specifically for use in inspecting tank vessels. This system uses a third-generation monochrome video camera and integral focusable lights. The camera/light unit can be lowered through a standard tank cleaning (Butterworth) plate on the deck of a tankship and is remotely controlled. The image is viewed on a monitor by a trained technician on deck, and if problems are detected, video tapes can be made. There is presently one system, located in Portland, OR. The system has been used primarily for inspections of the underdeck structure of tank vessels in conjunction with traditional walking surveys of the lower areas of the tanks. The system has been through several stages of development by NETS and BP, and is now considered by them to be suitably advanced for more widespread use. Accordingly, NETS has recently received permission from BP to market their tank vessel inspection services based on this system, and they will soon have additional units available.

### 3.4 Remote Video Cameras

Most remote video systems currently available for inspection purposes are special-use items which are not suited for tank vessel inspection. Many commercial remote systems are designed for close-up applications such as internal inspections of pipes or for medical applications, and while these systems are often very compact, they do not have either the magnification capability or the level of lighting needed for long-distance applications. Several magnetic crawler systems are available, but these are also short-range systems and are not designed for environments as dirty, as large, or as structurally complex as the inside of a single-bottom tank vessel's cargo space. As double-hull tankers become more common, devices of this type may be of some use in inspecting the bottoms and the smooth sides of the bulkheads in cargo spaces. However, the area covered per unit time by such devices is low.

One possible application of remote video systems similar to those now available is in inspecting the insides of pressure vessels such as air receivers which have only small openings. No remote video systems were tested during this project.

## 3.5 Equipment Purchased for Testing

Appendix B contains the complete list of equipment purchased for use in this study. This list also shows what equipment was evaluated in each test. The initial tests column in Appendix B refers to the initial screening tests discussed below.

## 3.6 Initial Screening Tests

The initial screening tests were performed at night by R&D Center personnel to determine equipment suitable for further testing. Some items were eliminated due to poor performance and some because of low durability. Some of the lights were received too late to include in the initial tests but were included in at least some field tests.

# 4 DESCRIPTION OF THE FIELD TESTS

Four field tests and one office session were conducted. The equipment list in Appendix B shows which items were evaluated on each of the field tests. Several general procedures were followed during all of the field tests.

> Fresh alkaline batteries were installed in all battery-powered equipment on the morning of each day of testing, and all rechargeable equipment was given a fresh charge, where possible, for each test day.
>
> Inspectors were allowed to select the equipment they found most interesting to bring into the spaces where the evaluations were conducted. However, MAR and R&D Center personnel also encouraged the inspectors to use equipment which they might not have been familiar with, but which, after trying, they might find valuable. For example, most inspectors had never used head-mounted lights and many of them did not, on their own, select these lights for testing. However, after being strongly encouraged to try them, many of the inspectors found them to be very useful. The inspectors at each of the tests were very cooperative, and agreed to at least do a quick evaluation of equipment which they did not initially feel would be useful.

The sections below summarize each of the four field tests and the New York office session. The contractor's trip reports for each of these tests, which form Appendix C of this report, describe the details of how the tests were conducted, the environment in which they were conducted, and the inspectors' initial evaluations of the equipment, as discussed with MAR and R&D Center personnel at the test locations.

## 4.1 James River Reserve Fleet Tests

The first test was staged on the *USNS Pawcatuck*, a former Navy fleet oiler, now in inactive status in the James River Reserve Fleet in Newport News, VA. The actual testing spanned three working days. The base for the tests was the main deck of the Pawcatuck. For this test, all of the equipment which passed the initial evaluation was shipped to the site and was made available. Instructors from the Yorktown marine inspection training facility and field inspectors from MSO Hampton Roads participated in the three days of testing. A different group of three to five inspectors was present for each day of testing, although several of the inspectors participated on more than one day.

Testing was done primarily in two differently configured centerline cargo tanks of the *Pawcatuck*, with a short trip into one wing tank. These tanks are considerably smaller than those of a crude carrier, but have similar internal structural members. The inside surfaces were rusty and were thus dark and nonreflective and provided a fairly demanding test environment for lighting equipment. There was no lighting in any of the tanks other than the portable lights being tested.

The contractor's trip report for the James River Reserve Fleet test is in Appendix C of this report. The findings from the test were used in preparing the reprioritized list of equipment which is presented in section 7 of this report.

## 4.2 Tests at Erie, Pennsylvania

The second test took place in Erie, PA, onboard two Great Lakes bulk carriers, which carry iron ore, coal, and other bulk cargoes. This test took place on one working day. Two inspectors from MSO Buffalo were present. They came specifically for this project, and were not there to conduct a regular inspection. An office in the Erie Marine Enterprises shipyard was used as a base. A limited amount of equipment, mostly portable lighting equipment, was tested. The test spaces were a ballast tank, a main cargo space, and a boiler on a 650 foot bulk carrier, and a main cargo space on a 1000 foot bulk carrier. The cargo space hatches of both bulk carriers were closed during the tests.

## 4.3 Tests at New Orleans, Louisiana

The third test took place at New Orleans, LA. The test was conducted from the West Bank Detachment of MSO New Orleans. The West Bank Detachment office was used as a base. Several inspectors from the West Bank Detachment took part in the test. Over the course of two working days, visits were made to an oceangoing derrick barge in drydock, to a double-hulled raised-deck tank barge in drydock, and to a double-hulled flush-deck asphalt barge in the water awaiting inspection. A potable water tank and a ballast tank were entered on the derrick barge. Several other inspectors examined equipment in the inspection office.

A number of items of lighting equipment were left at the West Bank office for longer-term evaluation. Questionnaires were provided to the inspectors so they could record their evaluations of this equipment.

## 4.4 Tests at Portland, Oregon

The fourth test took place in Portland, OR. The Portland shipyard branch office of MSO Portland was used a a base during this test. Five inspectors from the MSO Portland participated. Over the course of three working days, tests were conducted on a ferryboat under construction, a laid-up double-bottom crude carrier, and a double-bottom refined product tanker in drydock. The trips to the ferry and the product tanker were part of regular inspections; the trip to the crude carrier was done specifically for the purpose of evaluating equipment. On the ferryboat, a number of ballast, void, and engineering spaces were entered. On the crude carrier, one centerline and one wing cargo tank were entered, and on the product tanker, an external hull inspection was conducted, and one double-bottom space and the forepeak ballast tank were entered.

The inspectors reactions to the equipment they tested were recorded during and after the tests, and many of the items which were tested were left at the Portland shipyard branch inspection office for longer-term use and testing.

### 4.5 Evaluation by MSO New York

The fifth test took place at MSO New York. This was not actually a field test. A large selection of equipment, primarily lights, was shown to a gathering of inspectors in the office. The inspectors selected the equipment they felt they would like to test, and were encouraged to use a few other items. This equipment was left with them over a period of about one month, along with questionnaires to be filled out after the equipment was tested.

# 5 RESULTS OF THE FIELD TESTS

## 5.1 Overall Observations

Inspectors Needs and Preferences Vary

The field tests were conducted in a number of different inspection environments on various tankships and barges, as well as on several other types of vessels. A number of different inspectors participated. It became clear that there was no single "ideal" piece of equipment in many of the categories, particularly with lighting equipment.

A number of factors affect various inspectors' evaluations of inspection equipment, particularly lighting equipment:

Personal preferences - In many cases, two inspectors working under the same conditions preferred quite different types of lights. Working the same space, one inspector might prefer a small, light flashlight while another would be willing to carry a much heavier hand lantern for its greater intensity.

Type of ship - Various ship types require different types of lights. Inspectors who normally work bulk carriers, for instance, tend to have different requirements from those who normally inspect tankships.

Various Inspection Office Procedures - In offices like Portland, where inspections are normally conducted over a period of a week or more on ships undergoing repairs in local shipyards, inspectors rarely spend more than several hours at a time on board. At other offices, inspectors may spend long days on board. These differences result in different preferences for battery life, for rechargeable vs. disposable batteries, etc.

Inspectors' Experience with Innovative Equipment

Most inspectors presently carry as little equipment as possible. As a result, most inspectors have had very little direct experience with any inspection equipment other than flashlights.

Bulbs for Lighting Equipment

In the past, most portable lights used conventional incandescent or krypton flashlight bulbs, which are readily available almost everywhere. Most of the advanced lights tested in this project, including flashlights, use proprietary xenon or halogen bulbs or bulb/reflector units which are specifically designed for the particular light in which they are used. Replacement bulbs and bulb units for these lights are not readily available on the open market or through the government stock system. Because of this, inspection units or

individual inspectors who adopt these types of lights must be certain to obtain and to maintain an adequate supply of replacement bulbs.

Carrying Attachment for Lights

Virtually all of the lights, from the smallest flashlights to the large self-contained spot/floodlights, lack proper attachment points for carrying lanyards or straps. The larger lights that do have straps are still difficult to carry when descending ladders, and the strap systems need to be redesigned. To be useful in the inspection environment, a light needs a specialized carrying arrangement which is designed for both the particular light and for the unique conditions encountered in vessel inspection.

Rechargeable Equipment

Several inspectors commented on the potential difficulty of using rechargeable equipment, especially overseas where the charging equipment may not be compatible with the available electrical connections, or where charging connections may not be available. The Industrial Scientific multi-gas monitor, which has a relatively short battery life for this type of device, and a fairly long charging time, could be particularly troublesome in an overseas situation, especially if a number of inspections were being made on successive days.

## 5.2 Head-Mounted Lights

### 5.2.1 General Observations

Head-mounted lights clearly emerged from the testing as equipment which can improve inspector safety and efficiency at low cost and with very little inconvenience. Helmet lights should be available to all inspectors. Very few inspectors, (and none of the inspectors who participated in the tests) had previously used head-mounted lights. However, almost every inspector who tried them found that they would be useful at least in some inspection situations.

The smaller head-mounted lights with integral batteries were preferred over miners' lights with belt-mounted battery packs by all of the inspectors who evaluated them. Miners' lights are intended to provide a primary light source for hands-free close-up work for an extended amount of time. Although they are approved for hazardous locations, they are heavy and use belt-mounted battery packs with cords to supply power to the helmet unit. Inspectors found the weight and inconvenience of the battery pack and the discomfort and restriction of movement caused by the cords to be serious disadvantages. Inspectors prefer to use a hand-held light for their primary light, and therefore they see a head-mounted light as an adjunct to their flashlight, to help in lighting the way when moving about and climbing, when writing, and as an emergency escape light in the event their regular flashlight is lost or fails.

Most inspectors in Portland said that they normally climb ladders with their flashlights in a coveralls pocket, facing up, and lit, which does not provide good local illumination, especially when descending ladders. They often write notes in dark spaces by holding their flashlights in the crooks of their arms to illuminate their notebooks. After only one day of trying a headlight, one inspector who had never used one before said he couldn't imagine ever entering a tank again without one.

Considering the obvious safety advantages of using a head-mounted light and the fact that their use does not in any way hinder an inspector, they should be made available to all inspectors and the inspectors should be encouraged to use them. The head-mounted lights provide a constant, low level of illumination for climbing, making it unnecessary to manipulate a flashlight and leaving both the inspector's hands free for safety. When aimed downward, head-mounted lights provide excellent hand-free illumination for such tasks as writing, reading gas monitors, changing flashlight batteries, etc. In addition, a head-mounted light could prove to be a valuable beacon to help others find a disabled inspector in a large space. An observer on the main deck can very easily keep track of the people in a tank when they are wearing head-mounted lights. The head-mounted lights, especially the Pelican, also serve as an emergency escape light in case an inspector's regular flashlight fails.

Inspectors using headlamps found that they were less likely to keep their regular flashlights burning unnecessarily, for example, when moving around, climbing, resting, or writing, because the headlamp provided a constant, comfortable level of background illumination. It appears that the use of headlamps may extend the battery life of flashlights or allow brighter flashlights with shorter burn times to be used effectively.

### 5.2.2 Specific Evaluations

Inspectors considered only three of the small head-mounted lights to be potentially useful: the REI headlamp, the Pelican VersaLite, and the TopSpot convertible light. All of these lights have adjustable light heads, allowing vertical aiming of the beam. This is an essential feature. Only the REI light is waterproof, and only the Versa-Lite is approved for use in hazardous locations. Weight is an extremely important factor with head-mounted lights. For purposes of weight comparison, a typical hardhat with ratchet adjustment, chin strap and sweatband weighs about 1.1 lb.

The Pelican Model 2250 VersaLite, although it was not primarily designed as a head-mounted light, was the most popular, followed by the REI headlight. Both of these are self-contained units, and both can be adjusted easily over a range of vertical angles, a feature which proved to be essential for head-mounted lights in the inspection environment. The REI light is a bit brighter than the Pelican, but it is also heavier and tends to throw the hardhat out of balance and to cause neck fatigue after a day of use. The Pelican is light enough that the wearer really can't tell it is there.

Pelican VersaLite

This light emerged from the field tests as the inspectors' favorite head-mounted light. It is extremely small and light (0.17 lbs) and creates virtually no discomfort to the user, even when worn for long periods of time, but is only bright enough for short-distance illumination.

Both inspectors in New Orleans tried both the REI and Pelican VersaLite. They both found the head-mounted lights to be useful, and both preferred the VersaLite to the REI light, despite the higher light output of the REI unit. The VersaLites were mounted on the inspectors' hard hats with duct tape in one case, and with an REI headlight band in the other case.

**Figure 1 Pelican VersaLite**

The two principal disadvantages of the VersaLite are:

1. It is not designed for easy mounting on a hard hat. The elastic band supplied with the light is designed to mount the light directly on the user's head. It was necessary to improvise suitable mounting techniques. The rubber band supplied with the REI headlamp worked well for mounting the VersaLite, although the plastic side tabs of the VersaLite bend under the load and may eventually fail.

2. The light is switched by turning the lens on its threads. Even with the lens fully screwed in (the "on" position) the threads between the lens and the body are less than halfway engaged. The head is unscrewed to turn the light off, and the threads are engaged only about one turn with the light switched off. The switching must be done by feel only, since the light is mounted on the user's hardhat, and it is fairly easy to turn the lens a bit too far when switching the light off and have it inadvertently disassemble. This is particularly true when there are other sources of light (this is generally when a user would switch it off), making it hard for the user to tell from the level of illumination exactly when the light switches off. This problem could be easily corrected by a small design change. A positive switch would be a major improvement.

The VersaLite uses the same plastic, O-ring sealed light head as the Pelican MityLite (which is waterproof). However, the VersaLite's battery compartment is not waterproof, and the wire passage from the battery compartment through the swivel joint to the head renders the head unit non-waterproof as well. A waterproof version would be an improvement.

The version of the VersaLite used during the tests was not stamped for hazardous location approval, however, the most recent versions of this light are approved.

The VersaLite had satisfactory battery life. Fresh batteries were installed each morning, and many of the headlamps were used almost continuously during the day's tests, a period of about 4 or 5 hours. The light maintained full intensity for this time period.

REI Headlamp (No photo available)

This light is larger and brighter than the VersaLite, but is also heavier. In short-term use (up to 30 minutes) many inspectors preferred it to the VersaLite because of its brightness. However, when they used it for a longer time, most users found the weight (0.47 lb.), which is all at the front of the helmet, to be uncomfortable. Most inspectors who used headlamps for a few hours or more preferred the VersaLite.

The REI lamp has an excellent rubber mounting band, which weighs an additional 0.1 lb, and which works extremely well for mounting the REI light (and others) on a hardhat. During the field tests, inspectors often took these bands from the REI lights and used them to mount VersaLites on their hardhats.

The REI headlamp had satisfactory battery life. Fresh batteries were installed each morning, and many of the headlamps were used almost continuously during the day's tests, a period of about 4 or 5 hours. The light maintained full intensity for this time period. The REI headlamp is not approved for hazardous locations.

TopSpot

The TopSpot is a convertible flashlight. The handle, which contains four batteries in four separate compartments, splits apart and converts to a helmet band. This is the brightest of the three small headlamps. Even though the battery weight is distributed around the hardhat, inspectors found it heavy after long-term use, and it does not appear to be very durable. Each of the four battery compartments has a separate cover, and these could be easily lost when changing batteries. These covers also appear to be likely to pop off if the light were dropped.

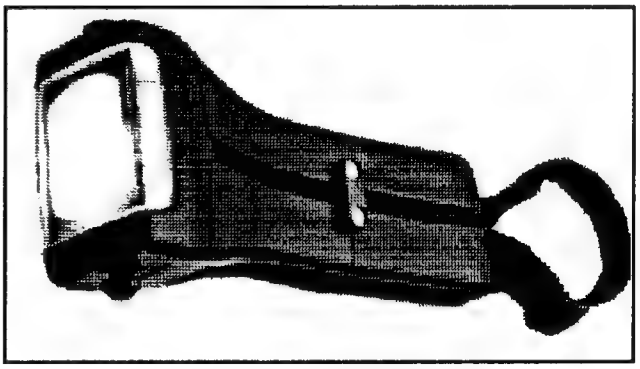


**Figure 2 Streamlight Top Spot II**

One inspector tried and liked this four-AA-cell light because it was brighter than the other two headlamps and because it could also be used as a hand-held light. However,

inspectors agreed that it was not durable enough for sustained use in an inspection environment. The rubberized pads allowed it to mount securely on a hard hat.

One inspector in Portland tried the Top-Spot and initially he liked it because it was more powerful than the other headlights and its beam could be focused. He felt that in tight quarters it might be usable as a primary inspection light instead of a hand-held flashlight. However, after using it for several hours, he decided that it was too heavy and too unbalanced to be used comfortably.

Koehler Model 5100

The only headlamp which was approved for hazardous locations was the Koehler Model 5100 belt-pack light. However, it required a special miners' hard hat with a mounting bracket, which inspectors do not have, so it could not be tested. However, inspectors who looked at it felt it was too heavy and the power cable was too much of an inconvenience.

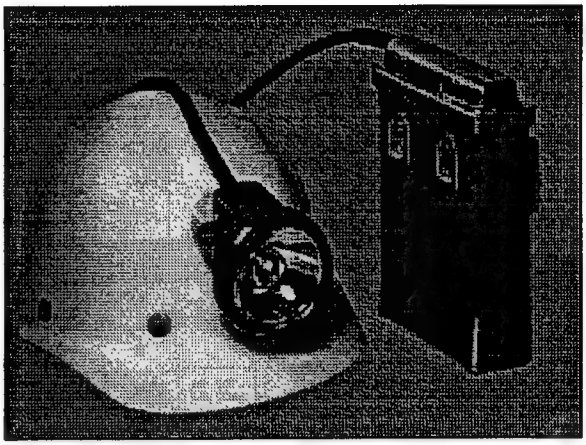


**Figure 3 Koehler Wheat Head Lamp**

## 5.3 Hand-Held Lighting Equipment - Flashlights

### 5.3.1 General Observations

The flashlights currently in use by Coast Guard inspectors range from the standard 3-cell approved government issue flashlight to much more advanced lights. In general, inspectors tend to use the flashlights issued by their particular inspection office, and there is a wide range here. While the "official" flashlight, that is, the one normally issued to every inspector, is often the standard GSA approved 3-cell light, some offices issue the more expensive Pelican Super SabreLite or the still more expensive rechargeable halogen Mag-Lite as standard equipment. In addition, a number of inspectors have purchased their own lights, and these range from diving lights to large hand lanterns. Most inspectors purchase small flashlights to use as escape lights. It was suggested that all flashlights should be colored yellow to make it easier to find them if dropped in a wet or muddy bilge.

The beam pattern of lights using standard flashlight bulbs (krypton or regular) seems to vary considerably with random variations in the heat-sealed top end of the glass bulbs. Other lights which use custom-made bulbs, for example the Pelican lights with their Xenon light units, showed much more consistency in beam pattern; the tops of the bulb units of these lights appeared to be uniformly spherical.

In general, inspectors favored lights having lanyards or clips over those with no means of attachment. The clips of the Pelican Super SabreLite and the lanyard of the

Pelican Pro got good reviews. Inspectors noted that lights which are small enough to be carried in a pocket should have both a pocket clip and an attachment point for a lanyard. It was suggested that hand lanterns and longer flashlights like the 3-cell Mag-Lite or the Pelican Pro should have two attachment points for lanyards, one near the tail end and one near the lens or head. [A two-point lanyard would solve many of the potential "loose-parts" problems when changing batteries or bulbs.]

Many of the newest generations of flashlights are diving lights or are patterned after diving lights. For watertight integrity many of these lights have only one opening - the connection of the lens to the body which is sealed by an O-ring. A number of lights use the lens-turn switching arrangement, in which twisting the lens moves the bulb into and out of contact with the batteries, eliminating the need for a separate switch. Several of these types of lights are approved for hazardous locations, and, with xenon or halogen bulbs and plastic cases, they offer high brightness for their weight. While these lights have advantages in terms of maintaining watertight integrity, they pose several disadvantages in the inspection environment:

- Lights using lens-turn switching require two hands to turn on and off - definitely a disadvantage to inspectors.

- The beam pattern is generally fixed - many inspectors prefer lights such as the Mag-Lite in which the beam pattern can be adjusted.

- In order to replace the batteries the entire light must be disassembled, exposing the bulb, reflector, switch contacts, and sealing O-ring to any dirt or dust which may be present in the environment. The parts are also difficult to control once the light is disassembled and they can be easily dropped or lost while changing the batteries. Lights with lens-turn switching have a spring which holds the reflector against the lens and which tends to make the parts fly apart when the light is disassembled. In some lights the spring is another loose part to be dealt with when the light is apart. Some times, the bulb/reflector unit must be carefully installed into the body of the light with an alignment keyway. Replacing batteries in these lights is difficult in the dark.

- The lens-turn switching mechanisms are prone to jamming in the "on" position, especially after becoming contaminated by dust. A jammed light must be disassembled to correct the problem, which could necessitate disassembly in a difficult location even if the battery life was sufficient to make battery changes unnecessary.

- It is possible to inadvertently unscrew the lens too far when turning the light off, resulting in an unwanted disassembly. This is particularly true with the Pelican Versa-Lite when it is mounted on a hardhat.

- Virtually all lightweight lights have plastic lenses, which are prone to degradation by scratching in the dusty environments found on many ships. Spare lenses would have to be carried by inspectors.

The flashlights which inspectors liked the most were the Super SabreLite, the Pelican Pro, and the Streamlight Survivor. Several inspectors said that they would carry one of these lights instead of their standard flashlight, however, others said that none of the flashlights tested were an improvement over their normal flashlight.

### 5.3.2 Specific Evaluations

Fulton N35 and N33

**Figure 4 Fulton Model N33 Flashlight**

The N33 is Fulton's version of the standard government-issue 3-D cell approved flashlight. The N35 is a two-cell model. As standard equipment, these lights have a regular incandescent bulb. Many inspectors use krypton bulbs in them but it is not certain that the hazardous location approval is retained when the bulb type is changed. The lights have plastic bodies and plastic lenses, are splashproof, but not reliably immersion-proof, and the beam pattern is not adjustable. In many inspection offices, the N33 model or a GSA counterpart is the light issued to inspectors as standard equipment. In terms of light output, this light is the least intense of all the full-sized flashlights tested. It is included in this evaluation as the low-performance baseline, to provide a standard known base of comparison for more advanced lights.

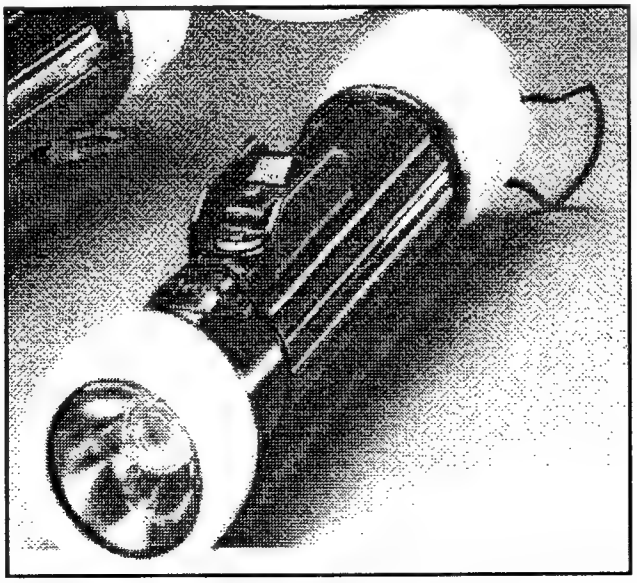


**Figure 5 Fulton Model N35 Flashlight**

Koehler 8400T

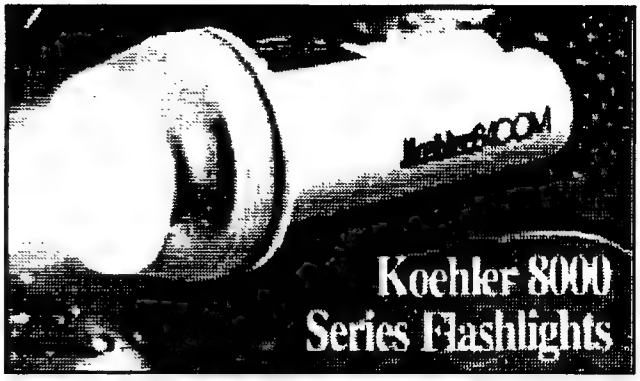


**Figure 6 Koehler Model 8400**

This is an small but extremely bright flashlight using 4 C-cells and a halogen bulb. Its brightness is equivalent to that of the Pelican Super SabreLite, but the beam pattern is considerably wider and is very consistent. Its beam pattern, while not adjustable, offered a good compromise between the narrow beam of the Super SabreLite and the wide diffuse pattern of the Pelican Pro. The 8400T has a separate switch for one-hand operation, which inspectors liked, but the batteries load through the lens cover, requiring disassembly and resulting in loose parts. However, one of the inspectors felt that it was easier to replace the battteries in this light than in some other similar lights. There is a single small lanyard attachment ring on the back of the light, but the light lacks a pocket clip, which would be very useful on a light of this size. However, the design of the pocket clip would have to differ from that of the Super SabreLite, since the lens unit of the 8400T is too large to allow it to be carried lens-down in a pocket. This light's shape is somewhat unconventional; the light is short with side-by-side battery compartments. Because of this short, wide body, many inspectors found the light somewhat uncomfortable to hold. The light is water proof and is approved for use in hazardous locations. All-around, this was one of the best small lights tested, and it appeared to be ideally suited to inspections of small spaces. With a good pocket clip, a longer, more slender body with a single long battery compartment, and a rear battery loading cap this would be the perfect small inspection flashlight.

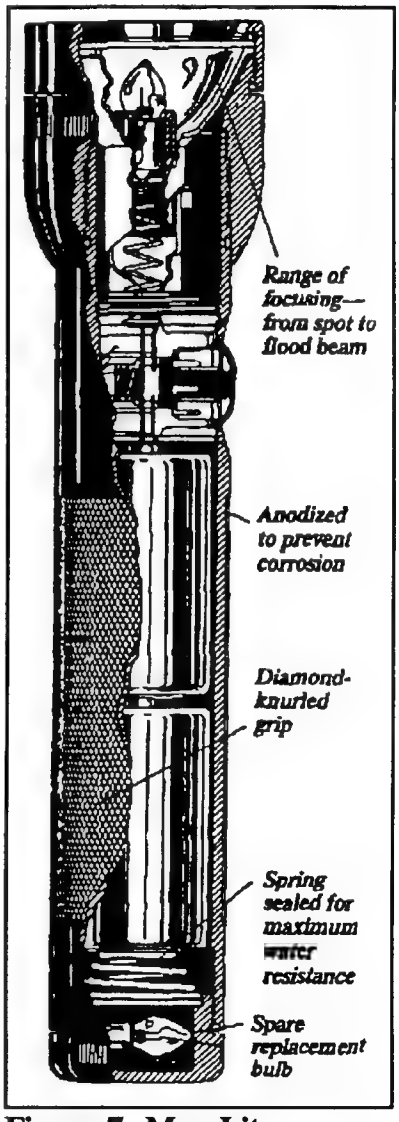


**Figure 7 Mag-Lite (typical)**

Standard Mag-Lites

The Mag-Lites are durable, heavy, aluminum-bodied flashlights with glass lenses. they are available in 2-C, 3-C, 2-D, and 3-D cell configurations, with obvious differences in weight, and some differences in intensity and battery life. Inspectors are familar with Mag-Lites, and the 3-D configuration seems to be the most popular with them. Many inspectors already use this light. Mag-Lites are available with standard flashlight bulbs and with the somewhat brighter

krypton bulbs (which are not as bright as xenon or halogen bulbs). All four models of Mag-Lites were tested in the James River Reserve Fleet test, with both standard and krypton bulbs. The 3-D unit with a krypton bulb proved to be the most popular.

While the krypton bulbs did not appear much brighter on deck, when compared side-by-side in a cargo tank, it was unanimously concluded that the krypton bulbs provided more intense light than the standard bulbs. Inspectors liked the adjustable beam pattern of the Mag-Lites, but disliked the irregularity of the beam and the dark spot usually present in the center. At least two inspectors said they would prefer one of the various Mag-Lite models (with krypton bulbs) to the standard flashlight.

Mag-Lites are waterproof but are not approved for use in hazardous locations. The 3-D krypton Mag-Lite is slightly brighter than the standard flashlight, and considerably heavier. The switch is a waterproof rubber push-button. The beam pattern is adjustable over a wide range from a wide flood to focused spot, however, over most of this range, the pattern is very irregular, with randomly located dark and light spots. Its beam was only bright enough for distant inspection when focused to the tightest spot setting. While inspectors in other ports had commented favorably on the Mag-Lite's adjustable beam pattern, the New Orleans inspectors did not find this to be a great advantage, because they generally do close-up inspections in barges.

The Mag-Lites load their batteries through a rear end-cap with a lanyard attachment point. The battery spring fits inside this cap, and the spare bulb is in a comparment under the spring. There is a tendency for the spring and spare bulb to separate from the end cap and fall when batteries are being replaced.

Rechargeable Mag-Lite

This light was not included in the initial identification and rankings, nor were any purchased for testing. The aluminum-bodied rechargeable Mag-Lite is the standard-issue flashlight at the Portland Shipyard branch office of MSO Portland. These lights are large and heavy and the battery life is minimal (about 1.5 hours). However, they have high-wattage halogen bulbs and they are very bright; they are also waterproof and very durable and can stand a drop from a considerable distance without permanent damage. They are not approved for use in hazardous locations. These lights, even when focused to a small spot, did not appear to adequately illuminate the upper parts of the tanks.

The rechargeable batteries are permanently built into the handle section of the light. Handle sections could be swapped to provide longer burn time, but the handle/battery section is heavy, and carrying extras would be quite a burden. The Portland office does not have extra battery packs for their lights. The lights are recharged by inserting the entire unit into a rather large charging fixture. No disassembly is required for charging, since there are two electrical contact bands which encircle the handle of the light and provide the connection for charging.

The lenses are glass, which eliminates problems with scratching during the frequent cleanings required in the normal inspection environment. These lights are well-suited to the inspection routine of the Portland office, in which many of the vessels inspected are within walking distance or a short drive of the office, and inspections are generally conducted piecemeal. All five of the Portland inspectors who participated in the tests used these lights and liked them. The Portland inspectors carry these lights by a continuous loop lanyard which they sling over their shoulders and around their chests. They have improvised a front attachment point for the lanyard from a piece of a bicycle inner tube. The end cap has an attachment point built in.

For inspection situations unlike those in Portland, OR, the short battery life and the inconvenience of carrying and swapping extra battery units would be a serious drawback. One important deficiency of the rechargeable Mag-Lites is that the small halogen bulbs mount in friction-fit two-pin sockets. The bulbs are easily dislodged by relatively minor impacts which are not otherwise damaging to the lights, and considerable disassembly is required to reset them. This is difficult in a dark location.

Pelican Super SabreLite


**Figure 8 Pelican Super SabreLite**

This is a small flashlight which uses a xenon bulb unit. It is waterproof and approved for use in hazardous locations. It has been used for several years as a standard flashlight by inspectors in a few inspection offices. It uses three C-cells which are for some reason loaded with the positive ends facing the back of the light, contrary to normal flashlight design practice. The Super SabreLite is small and light, and its beam is bright but is focused very sharply to a very narrow pattern. The beam pattern is not adjustable. Many inspectors found the sharp beam pattern to be a disadvantage, since it illuminates such a small area and makes it difficult to evaluate large features such as set-in areas of a sideshell.

The Super SabreLite would be more widely accepted if it had a switch which could be operated with one hand, like the Pelican Pro. The Super SabreLite switches by turning the plastic front lens. This feature has several important disadvantages as described in the general comments.

One feature of the Super SabreLite that most inspectors liked was the large, powerful, spring-loaded pocket clip. This clip allows the light, which is small enough to be carried lens-down in a pocket, to remain securely in the pocket. The clip also prevents the light from rolling when it is set down or dropped, which is an important feature that can prevent loss or damage.

Pelican Pro

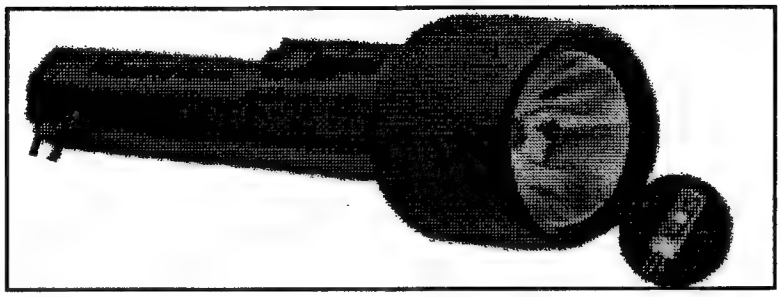


**Figure 9 Pelican Pro Flashlight**

This is a full-sized flashlight which resembles, but is in many ways an improvement over the Super SabreLite. It uses a plastic lens, a xenon bulb unit, 4 C-cells, and is waterproof and approved for hazardous locations. It has a number of features which inspectors found desirable, including a back-loading battery configuration with a separate battery cap, a one-hand switch, and a focusable beam. The light is long and slender, and can be carried lens-up in a pocket. Its beam is wider than that of the Super SabreLite, and the pattern is uniform but less intense than that of the Super SabreLite. The light is slightly brighter than a regular flashlight like a standard Mag-Lite or the GSA 3-cell light using a krypton bulb. There is an attachment point on the rear cap, but none on the body, and there is no pocket clip. The special bulb has two filaments, which can be switched independently using the three-position slide switch. This is an excellent safety feature in an inspection light; the Pelican Pro is the only light tested which had this feature. The range of focus of the adjustable lens is quite limited. The bulb has a 3-pin configuration and mounts in a friction socket. Inspectors who have had experience with this type of bulb mount (on the rechargeable Mag-Lite) caution that the bulb can jar loose if the light is dropped. Because the three-pin contact pattern of the bulb and socket are only slightly asymmetrical, replacing a bulb in the dark would be difficult. If a user attempted to insert the bulb in the wrong alignment, the pins could be bent or broken.

The performance of the Pelican Pro is similar to that of a 3-cell Mag-Lite, but it is much lighter and easier to carry. Many inspectors liked it despite the several minor deficiencies mentioned above. With a brighter halogen bulb, fitted for three D-cells instead of four C-cells, and with good lanyard attachment points on the body, the Pelican Pro might be the ideal standard inspection flashlight.

Pelican MityLite

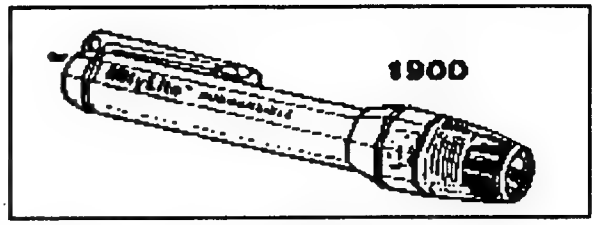


**Figure 10 Pelican MityLite**

The MityLite is a very small waterproof light with a plastic body and lens. It has a xenon bulb unit. It is approved for use in hazardous locations, and is the smallest flashlight which carries this approval. The MityLite is not sufficiently bright to be used as anything but an escape light. However, its extremely small size and light weight make it a good candidate for an inspector's escape light. A slight majority of inspectors preferred the UK Mini Q40 over the MityLite as an escape light. This light is smaller, lighter and brighter than the Mini Mag-Lite escape lights. Lab tests have indicated that it tends to overheat if used continuously, and that it shuts off when overheated.

Streamlight SL-90X Survivor

The Survivor is a fireman's light with a right-angle head and a halogen bulb. The beam cannot be focused. It uses an integral rechargeable battery which requires a special charging unit. This is an extremely high-quality light, and it is very durable. It is primarily intended to be clipped to the user's clothing and used hands-free.

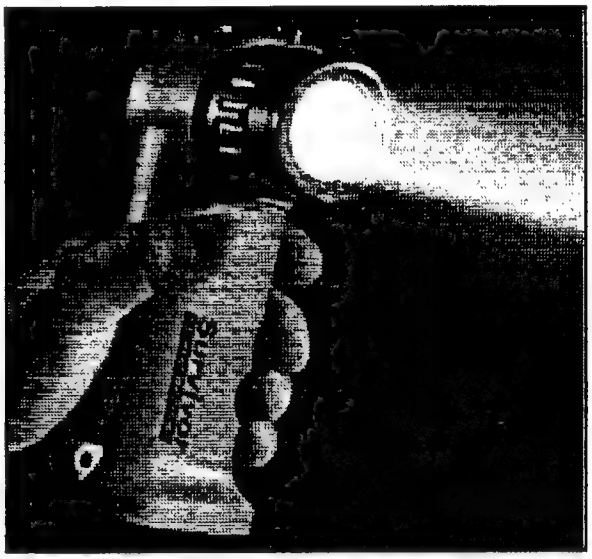


**Figure 11 Streamlight Survivor Model Sl-90X**

Underwater Kinetics Mini Q40

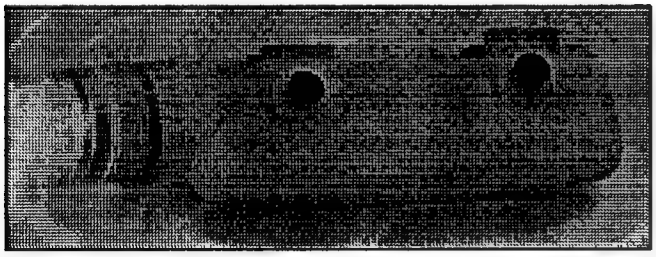


**Figure 12 Underwater Kinetics Mini Q40**

This is a very small waterproof pocket-sized light with a plastic body and lens, which is not approved for use in hazardous locations. It uses 4 AA-cells and a halogen bulb and it is very bright for its size. Many inspectors found this to be an ideal escape light. It is bright enough to be usable as an inspection light for small spaces, but its lens-turn, two-hand switching, fairly short battery life, and front-battery loading would be disadvantages in this use. These characteristics are not serious limitations for an escape light.

Brinkmann Legend System

This light was judged to be no improvement over current lights. It needs a better switch. The switch is difficult to work with gloves. Also, the spot portion of the beam is too small.

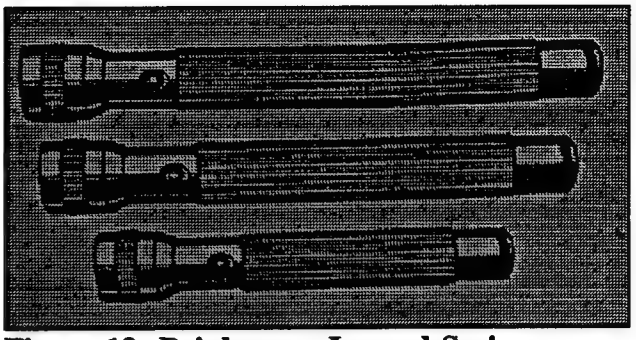


**Figure 13 Brinkmann Legend Series**

## 5.4 Hand-Held Lighting Equipment - Hand Lanterns

### 5.4.1 General Observations

Inspectors were, in general enthusiastic about the lighting power of the hand lanterns described in this section. However, virtually all of the inspectors who tried them disliked the pistol-grip handles. Inspectors clearly prefer a D-type handle mounted on top of the lantern to the pistol-grip handle underneath. Inspectors also prefer simple on-off toggle or slide switches to trigger switches.

None of the lanterns tested had effective carrying straps or suitable attachment points for straps. For lights as heavy as the UK 1200 or Pelican BriteLite, or as large and bulky as the NiteTracker RC-500K, carrying straps are essential.

The trade-offs between weight, intensity, and battery life become very evident with hand lanterns. The lantern with both high intensity and a reasonably long battery life (the UK 1200), is so heavy that most inspectors would be unwilling to carry it continuously. The light with high intensity and low weight (the RC-500K) has a very short battery life, and the light with reasonable weight and long battery life (the BriteLite) is not significantly brighter than the best flashlight. Observations of the UK 1200 and the Pelican BriteLite indicate that large lens diameters do not necessarily provide higher light output - the UK 1200 is brighter, but smaller in diameter than the Brite-Lite. Large lens diameter does make carrying and handling more difficult. One inspector pointed out (and demonstrated) that the Pelican Pro flashlight projected as much light as the BriteLite, despite its smaller size and lower weight.

During the evaluations, it became clear that there were in fact two categories of hand lanterns; smaller ones which could actually be carried around by the inspector comfortably for a reasonably long period of time, and larger ones which were best used as fixed lights, positioned to illuminate a large area while an inspector moved around and perhaps used binoculars to inspect the illuminated area. The lights in the first category generally were lighter in weight but with the bulb/reflector unit fixed to the case, so they had to be aimed continuously by hand. Those in the second category were heavier, but generally had a large stable base with a separately aimable bulb/reflector unit. These could be set down on a flat surface like the faceplate of a large longitudinal, a floor, or a web frame, and the light aimed

as desired. the inspectors envisioned different roles for the two different categories of lanterns.

The inspectors at Erie were less enthusiastic about hand lanterns, in general, than were the inspectors at the James River tests. There are few occasions on which a bulk-carrier inspector needs to project a high level of light a great distance to evaluate structural components. The inspectors tried all the hand lanterns in a darkened cargo space on the larger of the two bulk carriers visited, even though they would normally inspect this space with the hatches opened. The dimensions of this space were similar to that of a centerline tank on a VLCC. In general, they felt that the weight of the smaller (NiCad) battery pack was not objectionable. They preferred lights with on-off switches to trigger switches, even if the triggers had locking mechanisms. They were concerned about the effects of abrasive dust on the plastic lenses of many of the lights, and about the ruggedness of the lightweight plastic plug-in lanterns. One inspector liked one of the heavier self-contained hand lanterns despite its considerable weight. In general, they were less concerned about the weight of lighting equipment than tankship inspectors at the James River tests had been.

### 5.4.2 Specific Evaluations

LSI NiteTracker RC-500K

The NiteTracker RC-500K rechargeable light was almost unanimously rated as the best portable hand lantern. However, this light is not approved, it is not ruggedly constructed, and it has a short burn time (approximately 30 minutes). Inspectors liked its beam pattern and brightness, but felt that its 30 minute battery life was too short for it to be really useful.

The RC-500K was without a doubt the brightest and lightest hand lantern. It has a built-in rechargeable battery and has a large bulb and reflector unit similar to that of the battery-pack lights. Its lighting power in a dark space appears to be nearly equivalent to the 1,000,000 cp battery-pack lights. However, its short battery life limits its potential usefulness to only the shortest of inspections. The configuration of this light is identical to many of the 12V battery-pack lights, and like those lights, it needs a carrying strap which holds it close to the inspector's body while still allowing it to be used easily.

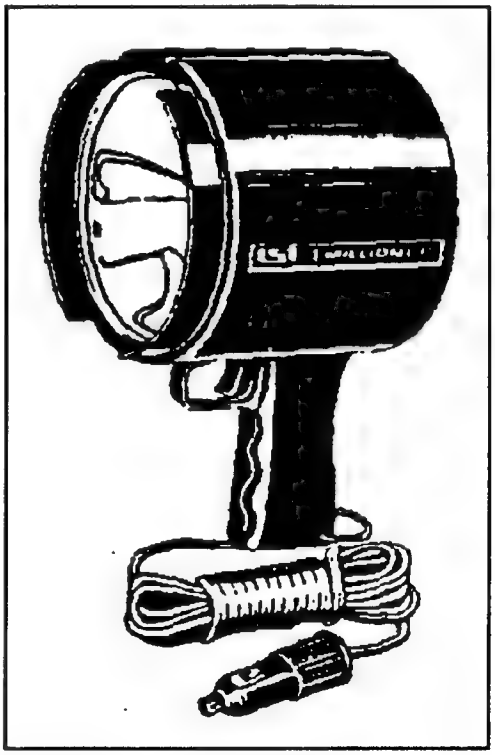


**Figure 14 Typical LSI NiteTracker**

Underwater Kinetics UK 1200

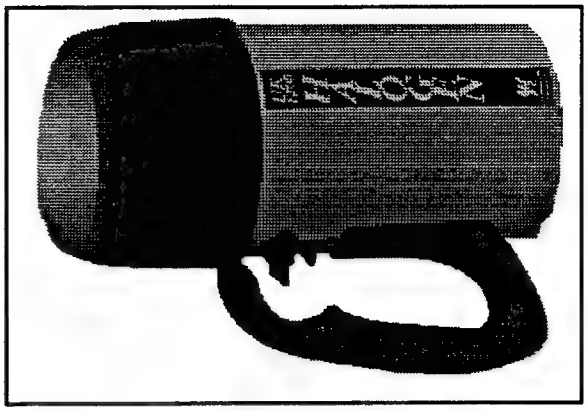


**Figure 15 Underwater Kinetics UK 1200**

This light is very bright and had a very uniform beam pattern, but it is heavy enough that some inspectors would not carry it. Only a few inspectors felt that the high intensity and acceptable battery life justified the weight. No inspectors liked the pistol-grip, which was very uncomfortable on a light this heavy. An optional D-handle, which was not on the unit tested, is available for this light. The switch lever was found to be broken during shipment before the Portland field tests. This appears to be a design deficiency. An inspectors' light should be able to take this kind of handling without failure. However, most inspectors judged the light to be a very high-quality and durable unit.

Pelican BriteLite

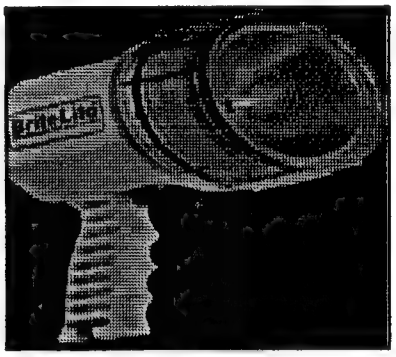


**Figure 16 Pelican BriteLite**

Only a few inspectors thought that the BriteLite would be useful in inspections. Most inspectors felt that its light intensity was not high enough to justify its weight and bulk. Most inspectors who tried it commented unfavorably on the pistol-grip handle. However, with its long burn time, it might make a good light for use with binoculars. The switches of both the Pelican BriteLite and the UK 1200 were difficult to use with gloves.

King Pelican

**Figure 17 Pelican King Pelican Pro**

This is a self-contained light which uses four D-cells. One inspector who used this light found it to be bright, but the switch was difficult to use. The model tested had the dimpled diffuser-type reflector. It is also available with a smooth surfaced spotlight reflector.

## 5.5 Hand-Held Lighting Equipment - Portable Spot/Floodlights

### 5.5.1 General Observations

The comments in section 5.4.1 apply to portable spot/floodlights as well.

### 5.5.2 Specific Evaluations

Collins Dynamics CD-12

Of all the portable spot/floodlights tested, inspectors preferred the Collins Dynamics CD-12. Despite being very heavy, it was the only one of the lights that could be set down and aimed that provided adequate light on both the spot and flood settings to allow an inspector to use binoculars to survey a distant surface. On its spot setting, the lighting intensity was sufficient to make out small details with binoculars at 50 feet or more. On its flood setting, it illuminated an entire tankship center tank, and illuminated a large area sufficiently for a binocular-assisted scan for defects.

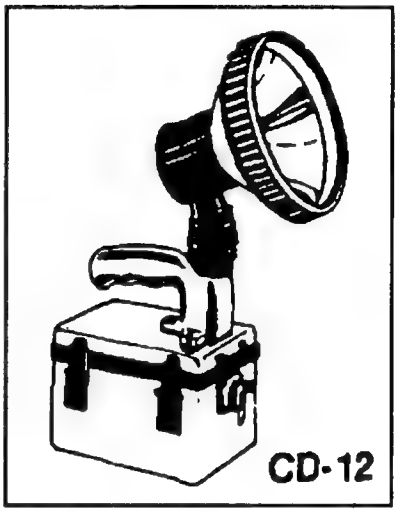


**Figure 18 Collins Dynamics CD-12**

For this light to be usable, a good carrying system will have to be devised. The shoulder strap provided with it does not allow the light to be carried in a comfortable position when climbing ladders.

One ship's chief mate thought that this light would be very useful and convenient for illuminating minor work in various internal and weather-deck spaces aboard ship, especially when the location of the work changes frequently. Cord-powered fixed lights are presently used in these situations.

Collins Dynamics Genesis 56/5

This light is considerably less bright than the CD-12, and most inspectors who tried it felt that if a large, heavy light was to be carried into a space, it should be the brightest one possible, even if it weighed a bit more. Therefore, no inspectors indicated that they would prefer this light to the CD-12.

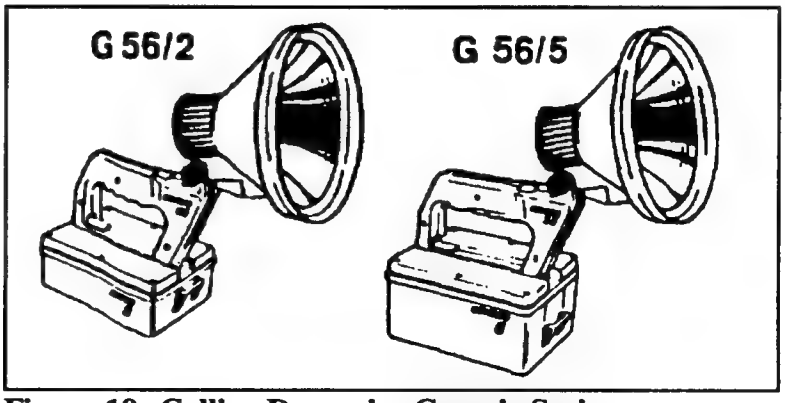


**Figure 19 Collins Dynamics Genesis Series**

Toplite Model 9050 and Toplite Model 9104

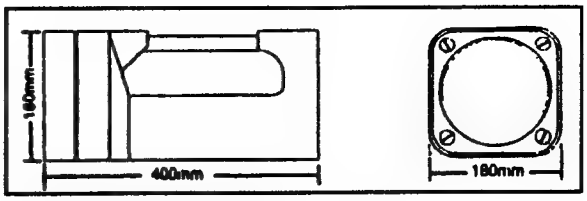


**Figure 20 Toplite**

The Toplite 9050 is the only large spot/floodlight approved for hazardous locations. However, since it carries British approval only, special permission would be required for it to be used by Coast Guard inspectors in hazardous locations. The model 9050 was the brightest approved portable light of any type tested during this project.

Inspectors felt that the Toplites were too heavy and bulky to be useful in internal inspections. The Toplites' lenses are fixed to the case, so the lights cannot be set down and aimed. In addition, the spotlight mode is only accessible with a momentary switch. For these reasons, and because of greater intensity, the Collins Dynamics CD-12 is superior. Some inspectors noted that in cases of nighttime casualty investigations involving ships or barges carrying flammable materials, a large approved portable floodlight like the Toplite model 9050 would be very useful.

## 5.6 Hand-Held Lighting Equipment - Battery Pack Lights

### 5.6.1 General Observations

Most of the battery-pack lights use standard automotive cigarette lighter plugs. Inspectors had considerable trouble with these coming unplugged inadvertently. In order for these lights to be useful, the plugs would need to be improved.

The cords of the battery-pack lights constitute a safety hazard. Many lights had cords which were significantly longer than they needed to be in this particular application. While the hazard created by the cords can never be totally eliminated, a tightly coiled cord which is no longer than absolutely necessary (about 30" stretched out) would minimize the problem of dangling cords.

None of the battery-pack lights had adequate carrying provisions. This type of light needs to have a continuous body strap which prevents the light from falling if the inspector lets go of it, and which holds the light close to the inspector's body while moving about but allowing it to be pulled out quickly to a usable position when needed.

As with hand lanterns, the great majority of the inspectors dislike the pistol-grip handles which most battery pack lights have. A light head more like that of a D-handle hand lantern would be preferable to most inspectors (the MaxaBeam light has this type of head). Virtually all of the inspectors who tried battery-pack lights preferred a simple on-off slide switch to a trigger, even if the trigger can be locked in the "on" position.

Inspectors felt that only the brightest of the battery pack lights were bright enough to justify the inconvenience of carrying them. The intensity of the Max Million and the LSI 1,000,000 lights (which are advertised as projecting 1,000,000 candlepower) is a minimum for this type of light. The inspectors who tried the battery-pack lights in the crude carrier said that this type of light would be useful during rafting inspections.

### 5.6.2 Specific Evaluations

Brinkmann Q-Beam Max Million

When a number of different battery-pack lights were tested together, the Brinkmann Max Million was the favorite of more than half of the inspectors.

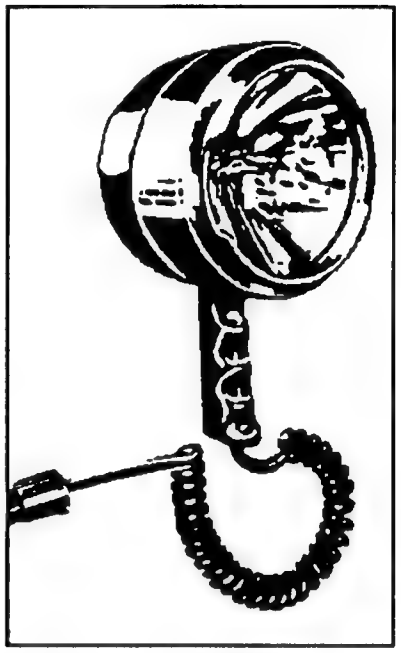


**Figure 21 Brinkmann Q-Beam Max Million**

This light is essentially equivalent in brightness to the LSI 1,000,000 CP light. Inspectors preferred the slide switch of the Max Million to the locking trigger of the LSI light. Inspectors indicated that in an appropriate situation, they would carry the Max Million and a battery pack. They were concerned about the apparent lack of durability of this light and the susceptibility of the plastic lenses to scratching in dusty environments.

Of the 12V battery-pack lights, the Max Million was judged to be the best by the inspectors because of its light weight, high intensity, good beam pattern, and convenient switch. One inspector felt that such a light would be used frequently in Portland if it was available. One inspector in Portland thought that it was the only light tested which offered a clear improvement over the Mag-Lite for inspections of large spaces.

Inspectors in Portland were interested enough in this light to suggest the following improvements:

A better plug (this problem is common to all lights with cigarette-lighter plugs). The plug pulls out of the battery pack socket too easily. Most of the lights and battery packs are available with, or could easily be adapted to, a marine two-prong 12VDC plug, which would be less likely to come unplugged accidentally.

Better carrying system. The light needs a strap or harness which allows the inspector to let go of the light without it falling to the ground. Some kind of shoulder strap with a flexible strap would allow the light to be carried close to the body, leaving the inspector's hands free, but allow it to be aimed and used quickly.

One inspector thought that a spot/flood capability would be desirable. The Blue Max light, which was not tested in Portland, does have a spot/flood bulb but its output on the spot setting is lower than that of the Max Million, and its spot beam pattern is not as clean as that of the Max Million.

Specialty Mobile Patrol Light

Some inspectors liked the Specialty Mobile Patrol Light, which is heavier and slightly less bright than the Max Million, and which has a less even beam pattern, but the Specialty light is smaller and appears to be much more durable than the Max Million, so it is more physically suitable for the inspection environment. This light's lack of a trigger lock was considered a disadvantage.

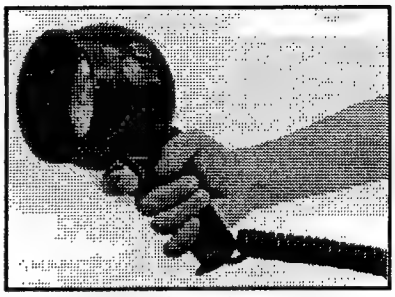


**Figure 22 Specialty Mobile Patrol Light**

Peak Beam Systems MaxaBeam

This is a very high-quality (but expensive) portable light. It was clearly the most intense light of any type tested during this project. It is most accurately described as a portable searchlight. The extremely white color of the light and the intensity make its illumination quite harsh. The power zoom is a nice feature, but on settings wider than a narrow spot, the beam pattern is not uniform. Some inspectors liked the Maxa-Beam for its exceptionally white light, but others felt that the dark spot in the middle of its beam pattern and the unnatural color of the light were a disadvantage. The on-off and spot/flood controls of the Maxa-Beam were difficult to operate with gloves, and inspectors repeatedly turned the light off trying to operate the spot/flood zoom control.

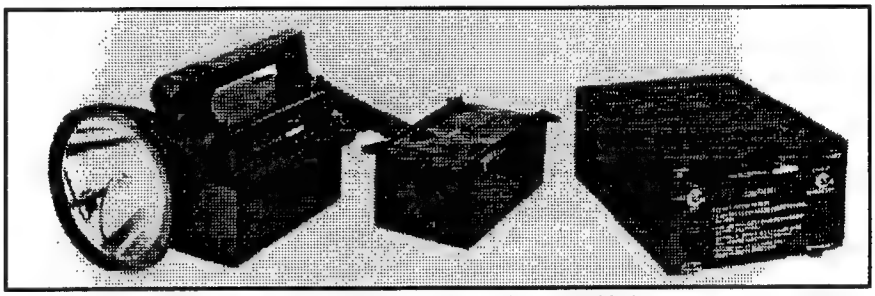


**Figure 23 Peak Beam Maxa Beam Searchlight**

The light head itself is quite light weight for a light of this intensity, but to get a reasonably long battery life, a lot of battery weight must be carried in the belt pack. While this light is most suited to longer-distance applications than most Coast Guard inspectors encounter, there might be an occasional inspection job, such as a need for telephoto photography of a distant corner of a large space, in which this light might prove useful.

LSI 1,000,000 CP

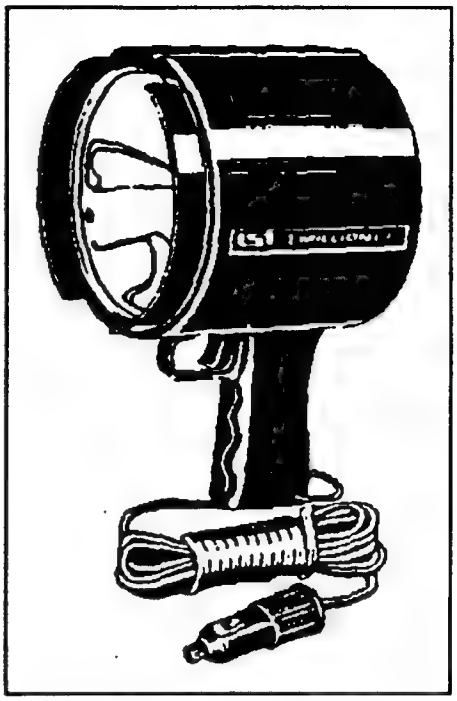


**Figure 24 LSI 1,000,000 CP**

This light is essentially equivalent in brightness to the Max Million. Inspectors preferred the slide switch of the Max Million to the locking trigger of the LSI light. They were concerned about the apparent lack of durability of this light and the susceptibility of the plastic lenses to scratching in dusty environments.

## 5.7 Telescopic Aids

### 5.7.1 General Observations

Most inspectors had not previously used binoculars during inspections of large vessels. The few who had tried binoculars had found that with only flashlight illumination the binoculars were not really an improvement over the inspector's unaided vision. The testing clearly showed that in order for binoculars to be effective, the level of light intensity provided by a portable spot/floodlight, a battery-pack light, or an exceptionally bright hand lantern is required. Lights used with binoculars must not only be bright, but they must illuminate a fairly large area at a high intensity. A small, bright, spot of light makes aiming the binoculars difficult.

With good illumination, most inspectors agreed that binoculars allow an inspector to see details of distant, inaccessible structure in tankship cargo spaces which could not be seen without magnification.

The coordinated aiming of binoculars and lights presents a problem. Many inspectors suggested that a rigid connection between the binoculars and a spotlight would help to solve this problem, and some inspectors experimented with this concept by taping binoculars to various lights. However, the combined weight of this arrangement is fatiguing. Another approach which worked well was to use binoculars in combination with a large portable floodlight, which could be set down on a surface such as the faceplate of a bottom longitudinal (or on the tank bottom of a double-bottom tanker) and aimed at an area. This strategy required a very powerful light which could illuminate a large area with sufficient intensity.

The smallest binoculars were found to be the most useful. In particular, the Unitron 7x21 fixed-focus binocular got good reviews. Despite their relatively poor light-gathering ability, the small size and light weight made them a clear favorite. Their fixed-focus optics were also an advantage over other binoculars requiring manual focusing, sometimes separately for each eye. The fixed-focus feature is a particular advantage in dusty and dirty

environments in which foreign material could contaminate the focusing mechanism of standard binoculars.

There is a trade-off in weight between binoculars and the lights which are required to make them useful. Larger, heavier binoculars provide brighter images and thus do not require as much lighting intensity as smaller binoculars, which have less light-gathering power. Conversely, smaller, lighter binoculars require larger, heavier lights.

Two magnification devices were tested in New Orleans, the Unitron mini-binoculars and a Unitrom monocular. The binoculars, which had been found very useful on previous field trials, had apparently become misaligned, and in this condition they were more or less useless. During previous field trials, these binoculars have been subjected to exactly the type of handling which they would be expected to encounter in an inspection environment, and a few hours of this handling have resulted in a great degradation in performance. It is clear that for them to be useful, they must either be made more resistant to minor impact and moderately rough handling, or some easily used and non-bulky protective carrying system must be devised. The padded case which the binoculars come with is more of a dust cover than a physical protective case.

The monocular provided a good image and was very compact and light. The necessity to focus it was a disadvantage - a fixed focus monocular might be better suited to the task (the Unitron binocular is a fixed-focus device). Inspectors found the use of a monocular awkward and unnatural compared to a binocular - the necessary squinting of one eye while using it is uncomfortable. It is possible that after using a monocular for a while, one might become accustomed to it. In our trials nobody has ever used it for more than a minute or so. The problems encountered with the binocular pointed out one obvious advantage of a monocular - it cannot lose its alignment due to rough handling, since there is only one set of optics.

In Portland, one inspector tried attaching the monocular to a light to solve the problem of simultaneous aiming; this experiment was inconclusive. The inspectors felt that the image was jittery, and that the field of view was small. They also had trouble maintaining balance when looking through the monocular. This was not a problem on the flat floor of a tank in a double-bottom ship, but it would be a problem in a single-hull vessel, where there are only narrow perches available. The jittery image and narrow field of view are related to the magnification, which, at 8 power, is at the high end for a low-mass hand-held device. A 6 or 7 power monocular would eliminate some of the jitter and would also provide a slightly wider field of view. Binoculars might be easier and less fatiguing to use than the monocular, and keeping balance is somewhat easier when using binoculars than when using a monocular. One inspector suggested attaching a magnification device (a small monocular or binocular) to a hard-hat so it could be flipped down when needed.

### 5.7.2 Specific Evaluations

Unitron 7x21 Binocular and Unitron 8x25 Monocular

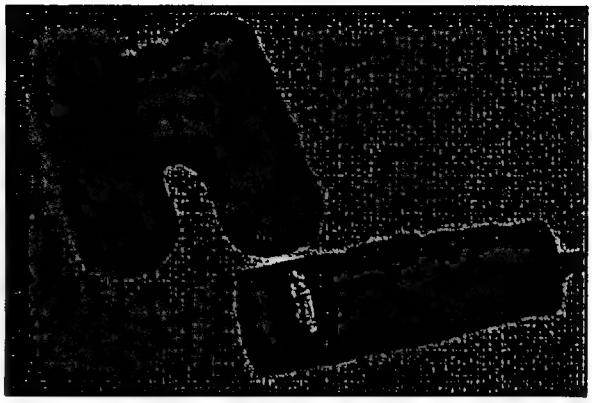


**Figure 25 Unitron Binocular 133F and Monocular 118B**

Many inspectors tried both the binoculars and the monocular. Virtually all of them preferred the binocular, because they felt it was awkward, uncomfortable, and unnatural to use the monocular for long periods of time. The fixed-focus feature of the binoculars was also an advantage, especially to inspectors who wear gloves and would otherwise have difficulty making adjustments on such a small device. Most inspectors who tried the binoculars indicated that they would be useful in certain situations, if combined with a powerful hand lantern battery-pack light, or portable spot/floodlight. The binoculars did not appear to offer any advantage when used with a flashlight.

The Unitron 133F (7x21) compact binoculars were very well received, much more so than any of the full-sized units. Unitron also makes 8x21, 8x25, 9x25, and 12x25 compact units in the same size and weight range as the 133F. Now that binoculars have been shown to have potential, and compact binoculars appear to be heavily favored over full-sized ones, it might be useful to compare and evaluate a number of different compact models.

## 5.8 Night-Vision Equipment

Night vision devices were not enthusiastically received. In general, they were perceived as fragile, complicated, and expensive, and as offering little in the way of improvement of detailed inspection of vessel structure. The American-made night-vision monocular (which had no magnification) was rated as the best device, however, it offered no advantage over a good portable light.

The performance of night-vision devices proved to be extremely dependent on accurate focus, as the depth of field is very shallow. Except for the ITT Night Mariner binoculars, all of the night-vision equipment tested required two focus adjustments every time the target distance changed slightly. Since the target distance is constantly changing as an inspector scans the interior of a large space, the constant focusing becomes tedious and seriously slows the inspection process.

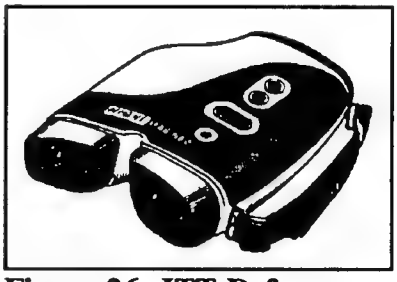


**Figure 26 ITT Defense Night Mariner Binoculars**

Of all the devices tested, only the ITT Defense night-vision scope provided an image that the inspectors considered usable. The resolution of all the other devices was too poor for them to be of use, even when considerable supplemental light was supplied (the resolution of night-vision devices improves considerably as the light level increases).

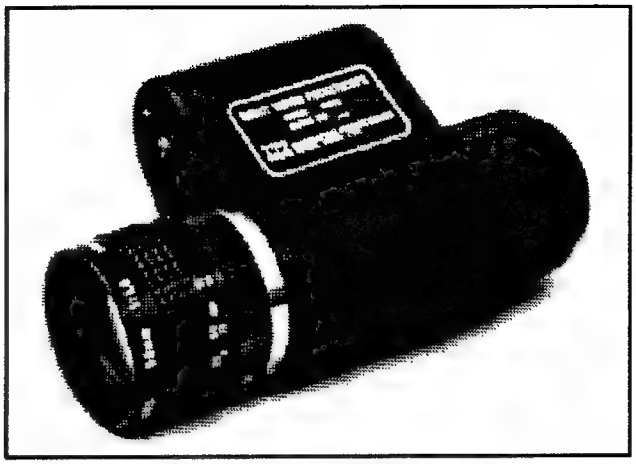


**Figure 27 ITT Defense Pocket Scope**

Even with the best device, however, the lack of magnification and the grainy, unnatural, green-colored monochrome image was not an improvement over unaided inspection with a flashlight. Night-vision equipment was included in the tests in the hope that the light-intensification would make it unnecessary to carry a large, heavy light to inspect distant surfaces in a large space. However, only two of the devices, the Night Mariner Binocular and one of the Russian devices, offered even a small amount of magnification, and the image quality of these devices was poor. The device with the best quality image, the ITT Defense scope, did not offer magnification. Without magnification, the inspector is more or less limited to flashlight range anyway, so there was no situation in which night-vision equipment offered any improvement over unaided vision with a flashlight. No night vision device was even remotely comparable to binoculars in combination with a powerful hand lantern, spot/floodlight, or battery pack light for observing remote parts of a large space.

## 5.9 Portable Gas-Monitoring Equipment

Of the two gas monitors tested, the inspectors reacted most favorably to the belt-mounted unit by Industrial Scientific, Model HMX271. The other monitor tested was the Neutronics Minigas Monitor. Many inspectors expressed a desire to carry gas monitors during all tank entries, and almost every inspector has stories of at least one colleague who has been "gassed". However, most inspectors do not now carry them routinely, because suitable units are not available to them.

For inspectors in the Lakes, explosive atmospheres and toxic gases are not generally a concern. Oxygen deficiency is the only common hazard. The inspectors interviewed in Erie said that their office uses the Neo-Tox oxygen meters, but that they are not satisfied with these. They would like a small, light, reliable meter for oxygen, and did not need explosive and toxic indication. Because of the tight-space problems crawling double-bottoms, belt-mounted units are difficult to use; a pocket-type meter is better. Inspectors in the Lakes region often work in very low temperatures, gas monitors for use there should be usable to at least -10 °F. The units we brought are usable down to about 0 °F.

The principal need of the New Orleans inspectors is for a reliable, easily carried oxygen monitor. They did not like the Neo-Tox units currently issued to inspection offices. They rarely enter a space in which explosive atmospheres might exist. The Industrial Scientific 3-gas monitor which we brought was somewhat large and bulky for inspectors working in and crawling through tight spaces. The inspectors did not mention any cases of $H_2S$ problems in their area.

### 5.10 Thickness-Gaging Equipment

Inspector saw no need for inspectors to carry ultrasonic thickness-gaging equipment; they prefer to have NDT technicians engaged by the vessel owner perform this work. One inspector felt that if CG inspectors carried and used this equipment, vessel owners might come to rely upon them for thickness-gaging. They pointed out that in many cases, the surface cleaning which the yard does in preparation for thickness-gaging by an NDT technician often results in penetration of the plating or other indications that renewal is clearly necessary. The plating is then renewed without any need for gaging.

### 5.11 Hand-Held Video Cameras

The one video camera available was not used extensively and no conclusions can be drawn as to its effectiveness at this time. Inspectors indicated that video cameras would not have a wide use for general inspections but may for investigations.

### 5.12 Carrying Systems

One of the inspectors tried the fishing vest and found that the pockets were useful for carrying equipment. He said he would prefer coveralls with more and larger pockets built in to the vest, however. Both inspectors said that suitable coveralls are hard to obtain, and that 100% cotton is preferable, especially in hot weather.

Inspectors did not like belt packs, since they tend to inhibit movement when moving through double-bottoms. However, they indicated that belt packs might be useful in other circumstances.

#### Fishing Vests

Inspectors were shown the various fishing vests and belts intended for carrying equipment. Most inspectors prefer not to wear anything outside their coveralls or hanging from the waist, since hanging objects can interfere greatly with climbing through manholes and other small access openings, especially in barges and double bottoms. Some inspectors have suggested that specialized coveralls with pockets designed specifically for the equipment which inspectors need to carry, would be preferable to carrying gear hanging on the outside of the coveralls.

One inspector in New York had obviously given the subject of carrying inspection gear some thought. He did not like the idea of a separate fishing vest worn on the outside of the coveralls since, feeling that the one-piece smooth surface of coveralls is an advantage in climbing through tight openings that should not be compromised by wearing equipment or other garments on the outside. He felt that a vest-type carrying garment which actually zipped onto the coveralls, leaving no exposed or hanging edges, would be best. This vest could be easily removed and left behind when access to an extremely tight space was necessary. In addition, several different types of zip-on vests could be used with the same basic coveralls in different inspection environments. Of the many ideas proposed by inspectors for improving their ability to carry equipment with minimal limitations on mobility, this is one of the best, and merits further consideration.

Equipment Belts

Inspectors universally disliked equipment belts because they get hung up easily when moving about the ship.

## 5.13 Combinations of Equipment

As was discussed in Section 5.7.1, the combination of binoculars with high-intensity lighting equipment makes it possible for inspectors to evaluate the distant structure, such as the underdeck structure in an tankship cargo space, more effectively than by any other means except direct physical access. The traditional combination of a standard flashlight and unaided vision appears to be fairly well-matched, but limited in range. In order to use binoculars effectively, more lighting power is required than can be produced by a standard flashlight, and in order to take advantage of larger, brighter lights, some form of visual enhancement is necessary, such as binoculars.

Flashlights which can project light to a great distance generally accomplish this by focusing it in a very narrow beam. Those flashlights having normal or wide beam patterns cannot illuminate distant surfaces (40 feet or more away) effectively enough to allow binoculars to be used. Because of the difficulty in aiming narrow light beams in coordination with magnification devices, flashlights with sharply focused beams are not effective with binoculars. And, normal or side-beam patterns from flashlights are not sufficiently bright to light distant surfaces and to overcome the loss of brightness inherent with small binoculars.

The combination of binoculars and very bright hand lanterns or portable spot/floodlights is promising. There are two likely strategies for using binoculars for inspecting distant tank structure, both with advantages and disadvantages.

The first strategy is the combination of binoculars and a bright hand lantern or a battery-pack light which could be carried more or less continuously by the inspector. The binoculars and the lantern are aimed simultaneously by the inspector as he or she scans the distant surface. In order for this strategy to be effective, the beam pattern of the light must

illuminate an area slightly larger than the full field of view of the binoculars, at a sufficient intensity that the visual resolution is comparable to that produced by a standard flashlight and an inspector's unaided vision on a reasonably close-up surface. The principal disadvantage is that the inspector must continuously support the weight of the light and must simultaneously aim both devices while moving about and maintaining balance. The advantage is that the light need not be as heavy as one used to implement the second strategy.

The second strategy is to use a large portable spot-flood light or a battery-pack light which is set down on a surface at the tank bottom and aimed up at the overhead structure. For this strategy to be effective, the light must provide an acceptable level of illumination to an area many times larger than the binocular's field of view, to minimize the moving and re-aiming of the light. The advantage of this strategy is that the inspector does not have to continuously support the weight of a heavy light, and he or she has both hands free to aim the binoculars and maintain balance. The disadvantages are that it requires a much larger, heavier light than the first strategy, and that the light must be re-aimed and moved frequently.

With the Unitron 7x21 binoculars, the RC-500 and the UK-1200 hand lanterns, and the Max Million, LSI 1,000,000, and the Specialty Mobile Patrol Light could be used to implement the first strategy. The Collins CD-12 spot/floodlight was the only light tested which could be used effectively for the second strategy. With appropriate aiming supports, the Maxa-Beam and the British Top-Lite would also be usable.

During the Erie tests in the cargo space of the larger bulk carrier, several cracked welds were discovered between a transverse bulkhead and its stiffeners. These were found by an inspector while the area was illuminated by a high-intensity 12V plug-in light held by another person located off-axis from the inspector's angle of view. These failures were then observed with several lights aimed from different angles, and with binoculars. Several rough conclusions were drawn from these observations.

These failures could not have been seen by the inspector from that diatance (15-25') with a standard flashlight.

The off-axis lighting helped to highlight the failures. Even using the high-intensity light, if the inspector aimed the light from his own position, the failures were not easily seen.

Binoculars, in combination with high-intensity lighting made it easier for the inspector to evaluate the failures from a distance.

Binoculars, in combination with the inspector's normal flashlight, did not allow the failures to be identified from a distance.

# 6 LABORATORY LIGHT TESTS

The tables on the following pages show the results of the laboratory light tests. All values in these tables are measured values except for the manufacturer's advertised life. Of particular importance is the initial intensity, the spot radius, the time to 1/2 intensity, and the life to burnout. These values often differ significantly from manufacturer's claims. However, in some cases the manufacturer's claims agreed very closely with the measured values. During light testing, the mode of failure was often light burnout rather than battery depletion. Lights that have a spare bulb stored inside in a location that permits the bulb to be changed in the dark offer obvious advantages.

## Summary of Flashlight and Headlamp Tests

| Light | Config-uration | Batt. | Bulb | Weight (oz) | Size (inches) | Date | Initial Intensity @ 10 ft (fcd) | Spot Radius @ 10 ft (in) | Time to 1/2 Intensity (hrs) | Life (hrs) | Mfr's Adv. Life (hrs) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flashlights | | | | | | | | | | | | |
| Fulton N35 | Full-size Flashlight | 2D Eveready | Std. | 15.5 | 2 Dia 8.25 L | 8/2 - 8/5 - 8/9 | 2.94 | 5"/ 4" | 27.5 hr | 53.5 | 19.2 | Changed bulb at 11.28 hrs Suspended at 22.5 hrs; and at 28 hrs |
| Fulton N33 | Full-size Flashlight | 3D Eveready | Std. | 23 | 2.25 Dia 10.25 L | 8/2 - | 2.66 | 11" | | | 35.0 | Bulb burned out at 2.0 hrs, test stopped. |
| (retest) | | 3D Eveready | | | | 8/5 - 8/9 - 8/10 | 3.25 | 5.5" | 3.0 | 26.8 | 35.0 | Same light. Suspended at 5.5 hrs. Bulb replaced at 11.5 hours |
| Underwater Kinetics Q40 | Mini Flashlight | 4AA Rayovac | Halogen | 4.5 | 1.5 Dia 5.5 L | 8/2 | 13.16 | 5" | 2.75 | 4.0 | 3 | Bulb burned out at 4.0 hrs. |
| (retest) | | 4AA Rayovac | | | | 8/5 | 19.72 | 5" | 2.25 | 4.05 | 3 | Different light |
| Pelican 2000C Sabre | Small Flashlight | 3C Rayovac | Xenon | 11.5 | 1.88 Dia 7.5 L | 8/2 | 22.7 | 4" | 3.0 | 4.5 | 6 | |
| Pelican 3500 Pro | Full-size Flashlight | 4C Rayovac | Xenon | 16.5 | 2.5 Dia 10.75 L | 8/2 | 4.2 | 15" | 2.5 | 4.25 | 6 | |
| (retest) | | 4C Rayovac | | | | 8/9 | 7.22 | 11" | .75 | 2.0 | 6 | Same light |
| Pelican 1900 Mity | Penlight | 2AAA Rayovac | Xenon | 1.5 | 0.75 Dia 4.75 L | 8/2 | 1.7 | 11" | 1.0 | 2.0 | 7 | |
| (retest) | | 2AAA Rayovac | | | | 8/9 | 1.58 | 11" | .75 | 1.65 | 7 | Same light |
| Koehler 8400M | Small Flashlight | 4C Rayovac | Halogen | 14 | 2.75 Dia 6 L | 8/2 | 10.91 | 11" | 2.25 | 4.0 | 5 | |

| Light | Config-uration | Batt. | Bulb | Weight (oz) | Size (inches) | Date | Initial Intensity @ 10 ft (fcd) | Spot Radius @ 10 ft (in) | Time to 1/2 Intensity (hrs) | Life (hrs) | Mfr's Adv. Life (hrs) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Light | Config-uration | Batt. | Bulb | Weight (oz) | Size (inches) | Date | Initial Intensity @ 10 ft (fcd) | Spot Radius @ 10 ft (in) | Time to 1/2 Intensity (hrs) | Life (hrs) | Mfr's Adv. Life (hrs) | Comments |
| Mag QC 6957 | Full-size Flashlight | 3C Rayovac | Krypton | 18 | 2.25 Dia 10.75 L | 8/5 | 14.52 | 5.5" | 2.75 | 4.16 | - | |
| Mag QC 4315 | Full-size Flashlight | 3D Eveready | Krypton | 23.25 | 2.25 Dia 12.25 L | 8/5 - 8/9 | 45.76 | 5" | 4.0 | 19.5 | - | Mechanical failure at 4.0 hrs, bulb replaced. Suspended at 5.5 hrs. |
| Streamlight SL-90 Survivor | Right-angle Flashlight | Recharg eable NiCad | Halogen | 15 | 3 W 3.5 D 7 L | 8/2 | 15.1 | 8" | 1.5 | 1.75 | 1.5 | |
| Headlamps | | | | | | | | | | | | |
| REI Waterproof Headlamp | Headlamp | 4AA Rayovac | Halogen | 7.5 | 5 W 2.5 D 3 H | 8/2 | 7.75 | 5" | 3.0 | 5.5 | 7 | |
| Streamlight 3000000 TopSpot | Headlamp /small flashlight | 4AA Rayovac | Halogen | 7.5 | 3.25 W 2 H 6.5 L (folded) | 8/2 | 18.87 | 5" | 2.0 | 2.5 | 4.5 | |
| (retest) | | 4AA Rayovac | | 2.75 | | 8/9 | 15.34 | 5" | 1.0 | 2.75 | 4.5 | Same light |
| Pelican 2250 Versa | Headlamp /small flashlight | 2AA Rayovac | Xenon | | 1 W 1.75 D 4 H | 8/5 | 1.42 | 6" | 2.25 | 4.16 | 7 | |
| (retest) | | 2AA Rayovac | | | | 8/9 | 1.81 | 6" | 1.0 | 4.28 | 7 | Same light |

Intensities are reported as weighted average of footcandle readings at center and four quadrants of spot, with each quadrant weighted 1x and center weighted 2x.

## Summary of Lantern and Spotlight Tests

| Light | Config-uration | Batt. | Bulb | Weight (lb) | Size (inches) | Date | Initial Intensity @ 10 m | Spot Radius @ 10 m | Time to 1/2 Intensity (hrs) | Life (hrs) | Mfr's Adv. Life (hrs) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Collins CD-12 Spot | Adjustable Spotlight w/ attached battery pack | Attached recharge-able | Halogen | 11.4 | 7.5 Dia 11.5 D 16.5 H | 8/10 | 196 | 24" | .63 hr | .63 hr | | |
| Collins CD-12 Flood | " | " | Halogen | | | 8/10 | 5.41 | 24" | 1.53 hr | 1.53 hr | 1.5 hr | |
| Collins Genesis 56/5 Spot | " | " | Halogen | 7.9 | 1.5 Dia 13.5 D 14 H | 8/10 | 94.9 | 24" | 1.41 hr | 1.41 hr | | |
| Collins Genesis 56/5 Flood | " | " | Halogen | | | 8/10 | .85 | 24" | 3.16 hr | 3.16 hr | 2.0 hr | |
| TopLite Flood | Fixed Spotlight | integral recharge-able | Conven-tional | 8.7 | 7 W 7 H 16 L | 8/10 | 7.74 | 24" | 1.25 hr | 1.25 hr | 1.1 hr | Similar approved model available. |
| Brinkmann Max Million Dynasty Lead-Acid Battery | Pistol-grip head w/separate battery pack | Dynasty Lead-Acid Pack | Halogen | 1.6 + 6.0 | 6 Dia 5 D 10 H | 8/10 | 61.3 | 24" | .75 hr | 0.8 hr | - | |
| Brinkmann Max Million NiCAD Battery | " | Again and Again NiCad Battery Pack | Halogen | 1.6 + 3.75 | | 8/10 | 53 | 24" | .75 hr | 0.75 hr | - | |
| Nitetracker RC-500 | Pistol-grip lantern | integral recharge-able | Halogen | 3.0 | 5.75 Dia 6 D 10 H | 8/10 | 41.4 | 24" | .48 hr | .57 hr | .5hr | |
| Pelican Brite-Lite | Pistol-grip lantern | 4D Eveready Alkaline | Xenon | 2.73 | 4.5Dia x 6.75L x 8H | 8/11 | 2.2 | 24" | 4.5 hr | 10 hr | 11hr | Approved. Double-element bulb. |

| Light | Config-uration | Batt. | Bulb | Weight (lb) | Size (inches) | Date | Initial Intensity @ 10 m | Spot Radius @ 10 m | Time to 1/2 Intensity (hrs) | Life (hrs) | Mfr's Adv. Life (hrs) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Light | Config-uration | Batt. | Bulb | Weight (lb) | Size (inches) | Date | Initial Intensity @ 10 m | Spot Radius @ 10 m | Time to 1/2 Intensity (hrs) | Life (hrs) | Mfr's Adv. Life (hrs) | Comments |
| Pelican Dual-Six | Pistol/D-handle lantern | 2 x 4D Eveready Alkaline | Xenon | 4.66 | 5.25Dia x 9.5L x 7H | 8/11 | 2.64 | 24" | 2.0 hr | 8.5 hr | 11hr | Approved. Two separate battery-bulb circuits. |
| Underwater Kinetics UK1200 | Pistol/D-handle lantern | 8D Eveready Alkaline | Halogen | 4.16 | 4.25Dia x 8L x 8H | 8/11 | 8.88 | 24" | 2.0 hr | 10.5 hr | 12hr | |
| Ikelite RCD | Pistol-grip lantern | 4D Eveready Alkaline | Halogen | 2.59 | 4Dia x 6.25L x 8.5H | 8/11 | 2.85 | 24" | 4.5 hr | 17 hr | 10hr | Suspended at 13.5 hrs. |

**Intensity reported as weighted average of footcandle readings at center and four quadrants of spot, with each quadrant weighted 1x and center weighted 2x.**

# 7 REPRIORITIZED LIST OF EQUIPMENT

The rating and ranking systems for the initial prioritization were based on the specifications of the items identified as potentially useful. Equipment which was actually tested is rated and ranked again in this section. These new ratings are based partly on the actual performance of the equipment as determined from inspectors' specific evaluations of each piece of equipment, and partly on specifications. Where specifications were used in developing ratings, general comments made by the inspectors during the tests were very helpful in evaluating the importance of the various specification categories.

Ratings are assigned for each element on a scale of 0 to 5. There are many cases in which a particular feature was not observed or commented on for a given item; these are marked "NA". Items listed as "characteristics" receive twice the weighting as those listed as "features". The overall rating for each device is the weighted average of the ratings for individual categories for which a rating is assigned, thus "NA" ratings do not affect an item's overall score.

The rating system presented here differs from the initial rating system. The changes reflect the input from inspectors on what characteristics they felt were most important to them.

## 7.1 Flashlights

Flashlight Rating System

Characteristics:

| | | | |
|---|---|---|---|
| 1 | Light Intensity | 0-5 continuous | 5 = 50 fcd @ 10 ft |
| 2 | Uniformity of Beam Pattern | 0-5 continuous | 5 = 10 in @ 10 ft |
| 3 | Weight | 0-5 continuous | 5 = 1 oz<br>1 = 25 oz |
| 4 | Size | 0-5 continuous | 5 = 5 cu in<br>1 = 50 cu in |
| 5 | Battery Life to Half Intensity | 0-5 continuous | 5 = 5 hours |
| 6 | Durability | 0-5 continuous | |

Features:

| | | | | |
|---|---|---|---|---|
| 7 | Focusing Beam | 0=no | 2.5=partly | 5=fully |
| 8 | Approved for Hazardous Locations | 0=no | 5=yes | |
| 9 | Scratch-Resistant Lens | 0=no | 5=yes | |
| 10 | One-Hand Operation | 0=no | 5=yes | |
| 11 | Attachment Points for Carrying Lanyard | 0=none | 2.5=1 | 5=2 |
| 12 | Ease of Battery Replacement | 0-5 continuous scale | | |
| 13 | Fit in normal coveralls Pocket | 0=no | 2.5= barely | 5=yes |
| 14 | Rolls when set down | 0=yes | 2.5=on steep slope | 5=not easily |

Flashlight Ratings

| Flashlight | Light Int. | Spot Rad | Wgt | Size | Bat. Life | Dur-ability. | Focus | Haz Loc | Lens | One Hand Ops | At-tach Pts | Bat Rep | Fits Pock | Roll | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fulton N33 | .3 | 5 | 1.3 | .8 | 5 | 4 | 0 | 5 | 0 | 5 | 2.5 | 4 | 5 | 0 | 2.71 |
| Fulton N35 | .3 | 2.5 | 2.6 | 2.5 | 5 | 4 | 0 | 5 | 0 | 5 | 2.5 | 4 | 5 | 0 | 2.76 |
| Koehler 8400T | 1.1 | 5 | 2.8 | 1.4 | 2.2 | 5 | 0 | 5 | 0 | 5 | 2.5 | 2 | 5 | 0 | 2.72 |
| Mag-Lite 3C | 1.5 | 2.7 | 2.2 | .6 | 2.7 | 5 | 5 | 0 | 5 | 5 | 2.5 | 3 | 5 | 0 | 2.74 |
| Mag-Lite 3D | 4.6 | 2.5 | 1.3 | 0 | 4 | 5 | 5 | 0 | 5 | 5 | 2.5 | 3 | 2.5 | 0 | 2.89 |
| Pelican MityLite | .2 | 5 | 4.9 | 5 | 1 | 5 | 0 | 5 | 0 | 0 | 0 | 3 | 5 | 1.5 | 2.84 |
| Pelican SabreLite | 2.3 | 2 | 3.2 | 3.1 | 3 | 5 | 0 | 5 | 0 | 0 | 2.5 | 3 | 5 | 5 | 2.88 |
| Pelican Pro | .7 | 5 | 2.4 | 0 | 2.5 | 5 | 2.5 | 5 | 0 | 5 | 2.5 | 4 | 2.5 | 0 | 2.64 |
| Streamlight Survivor SL-90X | 1.5 | 4 | 2.7 | 0 | 1.5 | 5 | 0 | 5 | 0 | 5 | 0 | NA | 2.5 | 5 | 2.34 |
| Underwater Kinetics Q-40 | 1.6 | 2.5 | 4.4 | 4.3 | 2.7 | 5 | 0 | 0 | 0 | 0 | 2.5 | 3 | 5 | 2.5 | 2.70 |

## 7.2 Hand Lanterns

Characteristics:

| | | | |
|---|---|---|---|
| 1 | Light Intensity | 0-5 continuous | 5 = 50 fcd @ 10 M |
| 2 | Spot Radius | 0-5 continuous | 5 = 2 ft @ 10 M |
| 3 | Weight and Size | 0-5 continuous | |
| 4 | Battery Life to Half Intensity | 0-5 continuous | 5 = 5 hours |
| 5 | Durability | 0-5 continuous | |

Features:

| | | | | |
|---|---|---|---|---|
| 6 | Handle | 0=pistol-grip | | 5=D-handle |
| 7 | Switch | 0= trigger | 2.5=locking trigger | 5=non-trigger |
| 8 | Attachment points | 0=0 | 2.5=1 | 5=two |
| 9 | Approved for Hazardous Locations | | 0=no | 5=yes |
| 10 | Scratch-Resistant Lens | | 0=no | 5=yes |
| 11 | Aimable when set down | | 0=no | 5=yes |
| 12 | Rolls when set down | | 0=yes | 5=no |

Hand Lantern Ratings

| Hand Lantern | Lgt Int. | Spot Rad. | Wgt & Size | Bat. Life | Dur-ability | Han-dle Typ e | Swit-ch | At-tach Pts | Haz Loc. | Lens | Ain-able | Rolls | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UK 1200 | .9 | 5 | 1.5 | 2 | 5 | 0 | 2.5 | 2.5 | 0 | 5 | 0 | 5 | 2.58 |
| Pelican BriteLite | .2 | 5 | 4 | 4.5 | 3 | 0 | 2.5 | 2.5 | 5 | 0 | 0 | 5 | 2.85 |
| Pelican DualSix | .3 | 5 | 1 | 2 | 3 | 5 | 2.5 | 5 | 5 | 5 | 0 | 5 | 2.95 |
| Ikelite RCD | .3 | 5 | 4 | 4.5 | 5 | 0 | 2.5 | 2.5 | 0 | 5 | 0 | 5 | 3.09 |
| LSI RC-500K | 4.1 | 5 | 3.5 | .5 | 1 | 0 | 2.5 | 2.5 | 0 | 0 | 0 | 5 | 2.25 |

## 7.3 Self-Contained Portable Spot/Flood Lights

Characteristics:

| | | | |
|---|---|---|---|
| 1 | Light Intensity | 0-5 continuous | 5 = 50 fcd @ 10 M |
| 2 | Spot Radius | 0-5 continuous | 5 = 2 ft @ 10 M |
| 3 | Weight and Size | 0-5 continuous | |
| 4 | Battery Life to Half Intensity | 0-5 continuous | 5=5 hours |
| 5 | Durability | 0-5 continuous | |

Features:

| | | | | |
|---|---|---|---|---|
| 6 | Spot/Flood | 0=no | 5=yes | |
| 7 | Carrying strap | 0=no | 2.5=fair | 5-good |
| 8 | Aimable when set down | 0=no | 5=yes | |

**Portable Spot/Flood Light Ratings**

| Light | Spot or Flood | Lgt Int. | Spot Rad | Wgt & Size | Bat Life | Dur-ability | Spot/ Flood | Carry Strap | Aim-able | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|
| TopLite 9050 | Flood | .8 | 5 | 1 | 1.2 | 5 | 0 | 5 | 0 | 2.38 |
| Collins Dynamics CD-12 | Spot | 5 | 5 | .5 | .6 | 5 | 5 | 2.5 | 5 | 3.44 |
| Collins Dynamics CD-12 | Flood | .5 | 5 | .5 | 1.5 | 5 | 5 | 2.5 | 5 | 2.88 |
| Collins Dynamics Genesis 56/5 | Spot | 5 | 5 | 1 | 1.4 | 2 | 5 | 2.5 | 5 | 3.18 |
| Collins Dynamics Genesis 56/5 | Flood | .1 | 5 | 1 | 3.2 | 2 | 5 | 2.5 | 5 | 2.70 |

## 7.4 Head-Mounted Lights

Of the head-mounted lights tested, only two received a significant number of favorable responses, the Pelican Versa-Lite and the REI Headlamp. Because of the limited size of this group, no quantitative rating system was developed. The Versa-Lite was preferred by a slightly larger number of inspectors than was the REI light. The Versa-Lite is lighter than the REI, light enough, in fact, that even after several hours of continuous use, its weight on the user's hardhat can barely be felt. However, its low intensity limits its use to navigating in dark spaces, climbing ladders, and writing. The REI light is heavy enough that its weight on the front of the user's hard hat throws the hardhat out of balance and causes discomfort to most users after a few hours. However, it is much brighter than the Versa-Lite, and it casts enough light that is is actually useful for inspection purposes in tight spaces.

The other headlamps fell into two general categories. The miners' lamps which used separate battery packs were judged by inspectors to be too heavy, too inconvenient to use, and too disruptive of the inspectors' mobility, despite their long battery life, bright beams, and approval for hazardous locations. Another group, including the convertible TopSpot and many others, were found to be insufficiently durable for the inspection environment, or to have other significant disadvantages.

# 8 RECOMMENDATIONS FOR FURTHER RESEARCH

In addition to the testing of equipment, the field tests also highlighted several cases in which advanced equipment which was not tested might help inspectors in their jobs.

## 8.1 Pressure Vessel Inspection Equipment

The machinery inspections for many types vessels require inspections of pressure vessels, primarily air receivers and boiler steam drums. While boilers generally have suitable access plates to allow a reasonable inspection, many air receivers have nothing more than a few pipe-size openings, often located at one end only. Inspectors find it very difficult to conduct a thorough internal inspection of many air receivers using their existing equipment. The current method is to use an inspection mirror inserted through the largest or most convenient opening, which is usually only a few inches in diameter, and to simultaneously aim a small flashlight to illuminate a small section of the inside of the tank while observing it with the aid of the mirror. The coordinated aiming of the light and observation is very difficult and is quite ineffective in a large tank. In addition, since the mirror offers no magnification, it is difficult to see details at the far end of the tank, which may be several feet from the nearest available opening.

There are two potential solutions to this problem: first, illuminate the entire interior of the tank with a small, intense, omnidirectional light which can be inserted through the opening, allowing room for the inspection mirror. Second, use a miniature video or fiber-optic imaging system with an integral coordinated light source. The first approach would be inexpensive, but would provide no magnification. The second approach would be more complicated and expensive, but would allow magnification in order to reach the far corners of a tank. The first approach is a logical, cheap, first step. A small, very intense light on a small-diameter stalk could be inserted in the tank. The time required for such an inspection is only a few minutes per tank, so the battery life of the high-wattage lighting device should not present a problem. In most cases, AC power is available in shipboard spaces containing air receivers, so battery power is not necessarily required at all. Borescopes could also be used if they can penetrate the full length/depth of the tank being tested.

The technology necessary to implement either of the schemes suggested above is readily available, however, no one system is available off-the-shelf which exactly meets inspectors' requirements for internal inspection of pressure vessels.

## 8.2 Remote Inspection of Chemical Tanker Ballast Tanks

The ballast tanks of chemical tank vessels, particularly foreign chemical tankers, are potentially very hazardous spaces. Corrosion of the lower parts of bulkheads is a problem in all ballast tanks. When the bulkhead separates the ballast tank from a chemical cargo space, a small leak can allow potentially dangerous cargoes to seep into the ballast tank. Inspectors have stories of rarely-used ballast tanks on chemical tankers containing mixtures of small

quantities of numerous hazardous substances which have seeped in over a length of time through a small rust penetration in a bulkhead separating the ballast tank from a cargo tank.

In some cases, OCMI's have told their inspectors not to enter these tanks, even though they are the most likely place for corrosion to occur, and are a fairly critical area for inspection. In many cases the residual substances in these tanks may be toxic, but they do not necessarily show up in standard tests for oxygen, explosive gas, or hydrogen sulfide. Chemical-specific tests would indicate the presence of problems, but the person doing the testing may have no way of knowing what substances to test for. Accordingly, it is difficult even for a competent gas chemist, using portable equipment, to determime with certainty that such a space is safe.

This is a clear application for a small remote video inspection system. Since the ballast tanks may be entered from other below-decks spaces which may be themselves somewhat difficult to get to, systems designed for use on deck to inspect the underdeck structure of a tankship may be too large and bulky for the job. The ballast tanks are not nearly as large as tankship cargo spaces, but the area of most interest to an inspector who cannot enter the tank is the lower part of the tank, rather than the underdeck structure as is the case with a tankship cargo space. This issue is discussed further in the trip report for the New Orleans field tests, located in Appendix C.

## REFERENCES

[1] Goodwin, M.J., and McClave, E.F. "Innovative Inspection Techniques", Volumes I and II, MAR Inc. report to USCG R&D Center, Contract DTCG39-91-D-E33A21, January, 1992.

# APPENDIX A EVALUATION OF INNOVATIVE VESSEL INSPECTION TECHNIQUES

This appendix contains the results of the initial phase of the project, which was the identification and ranking of equipment. Specifications, performance rankings, performance/cost rankings, a description of the ranking prodecures, and textual descriptions of the equipment listed are all included.

Report No.

# EVALUATION OF INNOVATIVE VESSEL INSPECTION TECHNIQUES

Edward F. McClave
Michael J. Goodwin
John Bernard

MAR, Inc.
6110 Executive Boulevard, Suite 410
Rockville, Maryland 20852

OCTOBER 1993

FINAL LETTER REPORT

Contract DTCG39-91-D-E33A21

Delivery Order DTCG39-93-F-E00502

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Research and Development Center
Groton, Connecticut 06340

(APPENDIX A)

**Technical Report Documentation Page**

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| EVALUATION OF INNOVATIVE VESSEL INSPECTION TECHNIQUES | October 1993 |
| | 6. Performing Organization Code |
| | 8. Performing Organization Report No. |
| 7. Author(s) McClave, E.F., et al | |
| 9. Performing Organization Name and Address<br>MAR, Inc.<br>6110 Executive Boulevard, Suite 410<br>Rockville, MD 20852 | 10. Work Unit No. (TRAIS) |
| | 11. Contract or Grant No.<br>DTCG39-91-D-E33A21 |
| 12. Sponsoring Agency Name and Address<br>U.S. Department of Transportation<br>United States Coast Guard<br>Research and Development Center<br>Groton CT 06340 | 13. Type of Report and Period Covered<br>Final Letter Report<br>June to October 1993 |
| | 14. Sponsoring Agency Code |

15. Supplementary Notes

16. Abstract

The U.S. Coast Guard is currently possibilities for improving the effectiveness of merchant vessel inspections by providing inspectors with improved equipment. A survey was conducted in 1992 to identify promising technologies. During this project, specific equipment in the categories of hand-held lights, deck-based lights, telescopic aids, night vision equipment, handheld video, and remotely operated video was surveyed.

Specifications of those devices which were potentially useful to Coast Guard marine inspectors were tabulated. Performance and performance/cost evaluation systems were developed and this equipment was ranked according to this evaluation system. Equipment which scored well in this evaluationBased on this evaluation, some Equipment was found to be potentially useful and was recommended for inclusion in field trials. Detailed textual descriptions are provided of the recommended equipment.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Merchant Vessel Inspection<br>Marine Inspection<br>Technology | |

| 19. Security Classif. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 118 | |

**Form DOT F 1700.7 (8/72)** **Reproduction of form and completed page is authorized**

(APPENDIX A)

Table of Contents





(APPENDIX A)

(APPENDIX A)

## LIST OF TABLES

# 1 Survey of Hazardous Location Regulations

## 1.1 Documents Reviewed

1. Title 29, Code of Federal Regulations (29 CFR) - Various Sections pertaining to the Occupational Safety and Health Administration (OSHA) (Text below discusses sections of particular interest)

2. 46 CFR - Various Sections (Text below discusses sections of particular interest)

3. U.S. Coast Guard Marine Safety Manual, Volume II.

4. National Fire Protection Association (NFPA) Pub. 306, Control of Gas Hazards on Vessels, 1993 Edition, National Fire Protection Association.

5. Guidance Manual for the Inspection and Condition Assessment of Tanker Structures, International Chamber of Shipping Oil Companies International Marine Forum, Tanker Structural Co-operative Forum.

6. Advancements in Tankship Internal Structural Inspection Techniques, Robert S. Holzman, ME thesis, University of California, Berkeley.

7. National Electrical Code (NEC), 1987 edition, by the National Fire Protection Association and the American National Standards Institute (ANSI).

## 1.2 Classification of Hazardous Locations

Articles 500-5, 500-6, and 500-7 of the National Electrical Code (NEC) define hazardous locations as those in which the danger of fire or explosion exists or may exist. Such locations are designated by Class, which describes the general nature of the hazard, by Division, which indicates whether the hazardous material is present in the air under normal conditions, and further, by Group, which indicates the specific nature of the hazard.

Class I locations are those in which flammable gases or vapors are or may be present in explosive concentrations. Class II locations are those in which combustible dusts are or may be present in explosive concentrations. Class III locations are those in which easily ignitable fibers are present.

Class I, Division 1 locations are those in which ignitable concentrations of flammable gases or vapors (1) can exist under normal conditions, (2) may exist frequently because of repair, maintenance, or leakage, or (3) in which breakdown or faulty operation of equipment might release ignitable concentrations of flammable gases and might cause simultaneous failure of electrical equipment.

Class I, Division 2 locations are those (1) in which volatile liquids or flammable gases are handled, processed, or used but in which those materials are normally confined in closed containers or systems from which they can escape only in case of accidental rupture or breakdown, (2) in which ignitable concentrations of flammable gas is normally prevented by positive ventilation, and which might become hazardous if the ventilation fails, or (3) adjacent to a Class I, Division 1 location and to which ignitable concentrations of gases might occasionally be communicated, unless this is prevented by positive-pressure ventilation and safeguards against ventilation failure are provided.

Class I locations are further categorized by the nature of the hazardous materials which might be found in them. These materials are grouped by the nature of and the degree of hazard they pose to humans. Group A is acetylene. Group B includes hydrogen and other gases similar in hazard to hydrogen. Group C includes some flammable gases and other toxic gases, and Group D includes all other flammable gases and vapors, including hydrocarbon vapors.

Class II locations are also designated by Division 1 and Division 2, depending upon whether the hazards are normally in the atmosphere or not. Class II locations are further categorized by Group. Group E includes combustible metal dusts and combustible, nonmetallic, conductive dusts. Group F contains coal, coke, carbon, and charcoal dusts, and Group G contains non-conductive combustible dusts.

### 1.2.1 Approved Devices

Equipment used in classified (hazardous) locations must be approved, as a result of testing, for the particular Class, Division, and Group of the hazard, or it must carry an overall designation, also resulting from testing and design review, which confers approval for a range of classified locations.

With only a few exceptions, the most hazardous locations which marine inspectors are likely to need to enter are Class I, Division 1, Groups C & D. Class I, Division 1 approval is conferred by Underwriters Laboratories, Inc. (UL), as a result of tests specifically designed for one or more of the groups of hazards. "Class I, Division 1, Groups C&D" approval is the most commonly encountered designation.

Class I, Division 2 approval is conferred by Factory Mutual Laboratories (FM) or the Canadian Standards Association (CSA) as a result of tests slightly different in nature from the UL Class I, Division 1 tests. "Class I, Division 2, Groups C&D, Non-Incendive" is the most commonly encountered FM and CSA approval. Class I, Division 2 approval does not mean that the equipment will not pass the UL test for Class I, Division 1, it only means that the equipment has been tested by FM or CSA rather than by UL. In fact most Class I, Division 2 approved equipment is suitable for use in Class I, Division 1 locations.

There is a separate Mine Safety and Health Administration (MSHA) test, and approval, for equipment to be used in methane atmospheres (which are included in NEC Group D). Some,

but not all equipment which passes the test for MSHA methane approval can also pass the UL test for Class I, Division 1, Groups C&D. The Coast Guard allows MSHA approved equipment to be used in Class I, Division 1 locations with the approval of local CG District Commanders.

### 1.2.2 Intrinsically Safe Devices

The NEC defines an **intrinsically safe** electrical circuit as "*one in which any spark or thermal effect produced either normally or in specified fault conditions is, under the test conditions prescribed in NFPA 493, incapable of causing ignition of a specified mixture of gas or vapor in air in its most easily ignited concentration.*" (NEC (1987) 500-2)

Intrinsically safe electrical equipment typically operates on voltages of 12V or less, and the power output of light bulbs in intrinsically safe equipment is usually limited to 50 watts. Intrinsically safe equipment is, by its nature, safe for use in any Class I, Division 1, Groups C & D hazardous location.

### 1.2.3 Explosion-Proof Devices

**Explosion-proof** equipment is defined as "*Apparatus enclosed in a case capable of withstanding an explosion of a specified gas or vapor which may be within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and which operates at such an external temperature that a surrounding flammable atmosphere will not be ignited directly.*"

Explosion proof-equipment must not only be strong enough to resist the force of an internal explosion caused by leakage of explosive vapors into its case, but must also be able to vent the internal pressure caused by the explosion, to cool the vented combustion products to an acceptable level before they are vented, and to absorb the heat of the explosion without an unacceptable rise in its external temperature. As a result of these requirements, explosion-proof equipment and explosion-proof enclosures for non-intrinsically safe equipment tend to be fairly heavy and bulky. Equipment which is **explosion-proof** must have specific approval for a given type of hazardous location.

## 1.3 Personnel Safety Requirements

Personnel safety requirements fall into two general classes, those concerned with the atmosphere in spaces to be entered and those concerned with the physical safety of people working in the space. There are differences between the reviewed publications but the differences are mainly differences in the degree of safety required.

The order of precedence of regulations is not spelled out explicitly, however, for Coast Guard personnel, the U.S. Coast Guard Marine Safety Manual (MSM) is the primary reference, as it covers many specific situations which are not covered in more general regulations. Part 29, CFR (OSHA) and 46 CFR both contain general guidance which is in many cases amplified

by the MSM. Parts of other publications, such as the NEC and other NFPA publications generally are invoked by reference in the MSM and applicable portions of the Code of Federal Regulations.

1.3.1 Space Atmosphere Requirements

OSHA

29 CFR 1910.1000 gives the concentrations of various hazardous substances that can be present in the atmosphere of the space. These standards seem to be generally agreed upon by all.

OSHA also published a Final Rule on confined space entry requirements on 1/14/93. These requirements are now 29 CFR 1910.146. In 1910.146(d)(5)(iii) OSHA requires that a confined space, including cargo tanks, have:

(a) Level of explosive gases < 10% of the Lower Explosive Limit (LEL)
(b) Oxygen content between 19.5% and 23.5%
(c) Atmosphere must not contain contaminants above permitted levels of any regulated substance (1910.1000)

Also, before entry, space must be monitored by a direct reading instrument for the above items. Entry must be authorized by a qualified person. If entry space is large, e.g., a cargo tank, it must be monitored continuously for the above items (1910.146(d)(5)(i)). This means entrants must have a monitor with them at all times. Also applying is 1910.146(d)(3)(v) which states that space atmosphere must remain acceptable throughout entry. The only way to determine this is through continuous monitoring.

OSHA does not specify a separate limit for hot work operations in a confined space. By stipulating a maximum of 10% of the Lower Explosive Limit, OSHA is inferring that any atmosphere that a worker is permitted to enter is free from explosion hazards. In other words, an ignition source will not cause an explosion.

Guidance Manual for the Inspection and Condition Assessment of Tanker Structures

The following rules are accepted by the international tanker inspection community:

Explosive gases < 1% of the LEL

Benzene < 10 ppm

$H_2S$ < 10 ppm

Oxygen > 21%

HC < threshold limit value (8 hour exposure/day)

| | |
|---|---|
| CO < 50 ppm | Where Inert gas systems are used |
| $NO_2$ < 3 ppm | |
| NO < 25 ppm | |
| $SO_2$ < 2 ppm | |

For a tank to be safe for hotwork, all sludge, scale and sediment must be removed in an area 10 meters in all directions from the work area. By inference, if the whole tank is declared safe for hot work, all sludge, scale and sediment must be removed.

U.S. Coast Guard

The Coast Guard refers to NFPA 306, reference 4, in numerous sections of 46 CFR (35.01-1, 71.60, 91.50, 109.573, 167.30, and 189.50) and in the Marine Safety Manual (5.D., and 5.I.). This document gives the requirements for certifying marine chemists and provides the rules that marine chemists have to follow in certifying a space safe for entry and safe for hot work. These rules are the standards through reference in 46 CFR. The definitions from NFPA 306 of interest are repeated below.

"2-3.1 SAFE FOR WORKERS. Means that in the compartment or space so designated:

(a) The oxygen content of the atmosphere is at least 19.5 percent and not greater than 22 percent by volume;

(b) The concentration of flammable materials is below 10 percent of the lower explosive limit;

(c) Any toxic materials in the atmosphere associated with cargo, fuel, tank coatings, inerting mediums, or fumigants are within permissible concentrations at the time of inspection; and

(d) The residues or materials associated with the work authorized by the Certificate will not produce uncontrolled toxic materials under existing atmospheric conditions while maintained as directed on the Certificate.

(e) If any of the conditions of 2-3.1(a), (b), (c), or (d) do not exist, then the designation "Not Safe for Workers" or "Enter with Restrictions" shall be used."

"2-3.4 SAFE FOR HOT WORK. Means that in any compartment or space so designated:

(a) The oxygen content of the atmosphere is not to exceed 22 percent by volume,

(b) The concentration of flammable materials in the atmosphere is less than 10 percent of the lower explosive limit,

(c) The residues are not capable of producing a higher concentration than permitted by 2-3.4(a) or (b) under existing atmospheric conditions in the presence of hot work and while maintained as directed on the Certificate, and

(d) All adjacent spaces, including diagonal spaces, containing or having contained flammable or combustible materials, are sufficiently clean to prevent the spread of fire; or are inerted, or, in the case of ship's fuel oil tanks or lube tanks, or engine room or fire room bilges or other machinery spaces, have been treated in accordance with the Marine Chemist's requirements.

(e) If any of the conditions of 2-3.4(a), (b), (c), or (d) do not exist, the designation "Not Safe for Hot Work" must be used."

Though not specifically stated above, 2-3.4(c) is often interpreted to mean that all sludge, scale, and sediment must be removed from the tank before a Safe for Hot Work designation is granted. This is similar to standards in Reference 5. This cleaning requirement is the principal difference between the two designations above. In nearly all cases, the space must be Safe for Workers and Safe for Hot Work before hotwork can begin.

The Coast Guard also refers to spaces as being "gas free" or "gas freed" in 46 CFR. It is unclear how this designation relates to the designations in NFPA 306. We believe that "gas freed" is the same as "safe for hot work."

No regulations were found that require workers to carry emergency escape breathing apparatus. This appears to be an internal Coast Guard rule only.

1.3.2 Equipment Requirements for use where Explosive Hazards may be Present

Explosive atmospheres may be present inside tanks and near tank vents and other openings on deck. 29 CFR 1910.106 and the National Electrical Code (NEC), NFPA 70, give guidance on what spaces are considered classified locations meaning that explosion or fire hazards may be present.

As a basic rule, if a space is declare Safe for Hot Work, any device may be used while inspecting the space. If a space is Safe for Workers only, then 46 CFR 111.105 requires that electrical equipment be intrinsically safe. However, self contained, battery fed, explosion proof lamps are acceptable. Devices, other than electrical devices, that could produce sparks are also banned but small hand tools are allowed (35.30-35).

OSHA has restrictions similar to the Coast Guard on the use of spark producing devices in hazardous spaces (e.g., 1910.106(b)(6)). Section 1910.307(b)(1) defines intrinsically safe as

usable in any classified location. OSHA refers to the National Electrical Code, NFPA 70, for a list of hazardous gases classed by their ignitable and combustible properties. OSHA considers a device safe for a classified area if it meets the requirements of NFPA 70. The Coast Guard also refers to the National Electrical Code in determining classified locations. Generally, all cargo areas on tankers fall in the Class I, Division 1 classification which is the most severe from a fire danger standpoint.

Reference 5 requires lighting to be intrinsically safe but indicates that explosion proof fixtures are acceptable in spaces not safe for hot work. It also states that most ultrasonic thickness measuring devices are not intrinsically safe, and non-intrinsically-safe devices must only be used in spaces safe for hot work.

### 1.3.3 Climbing Restrictions

No restrictions on climbing were found in 46 CFR. The international tanker inspection standards in reference 5 state that there should be no climbing on ship structures over 3 meters from the bottom or 6 meters over water. Some Coast Guard Inspection and Marine Safety offices are known to have local rules regarding climbing of structures but there apparently is no Coast Guard wide policy.

OSHA has extensive rules on the use of ladders of various types under Subpart D - Walking and Working Surfaces (1910.23, .24, .25, .26, and .27). Portable wood ladders are restricted to 40 foot maximum height. The height of metal ladders is allowed to be 30 feet for single sections, 48 feet for double sections, and 60 feet for three section ladders.

Fixed ladders are covered in 1910.27. This section specifies dimensions for ladder features. Cages are required on ladders greater than 20 feet and less than 30 feet high. Landing platforms are required every 30 feet, with railings and toeboards. Ladder safety devices are acceptable on ladders over 20 feet high in lieu of cages. In certain cases, landing platforms are not required such as on towers, water tanks, and chimneys where such platforms are impractical.

1910.28 and .29 cover the requirements for scaffolding. Sections 1910.66, .67, and .68 cover the requirements for powered platforms, manlifts and vehicle-mounted work platforms. These rules address the expected dangers of working up to great heights.

No regulations were found covering rafting inspections. Reference 5 provides some guidance that is not regulatory in nature. Most Coast Guard Officers in Charge of Marine Inspection (OCMIs) give local guidance to their inspectors on rafting procedures.

OSHA is considering new regulations covering fall safety in industrial environments, but as of the date of this report no final rule has been published. These regulations will apply to climbing of the type done by CG marine inspectors.

1.3.4 Noise Exposure.

OSHA regulations in 1910.95 cover occupational noise exposure. These regulations apply to all workplaces and have direct applicability to marine inspections which often must be conducted in high noise areas.

## 2 Evaluation Procedures for Inspection Equipment

The following categories of equipment are included in this survey:

- Lighting equipment
  - Hand-held lighting
  - Head-mounted lighting
  - Portable fixed lighting
- Telescopic Aids
  - standard monoculars and binoculars
  - stabilized monoculars and binoculars
- Night-vision Equipment
- Polarized-filter contrast enhancement devices
- Video Equipment
  - Deck-mounted video imaging equipment
  - Remotely operated video imaging equipment
  - Hand-held videotape recorders

A large number of manufacturers were contacted for information about equipment in every category. After reviewing the literature supplied by the vendors, equipment which was clearly not suitable was dropped from further consideration. The primary criterion at this stage was the ability of the equipment to make the initial screening stages of a marine inspection more effective or more efficient. During this stage of evaluation, equipment which offered no improvements over present technology, which was too heavy, to large, or required a large number of people to operate was excluded. No equipment was excluded as result of price alone.

Important characteristics of each type of equipment were identified, and a specification chart was prepared in matrix format for each type, including all devices which show promise. A performance and cost rating system was also defined for each type of equipment. Performance ratings and performance/cost ratios are reported for each device.

### 2.1 Performance Ratings

For each class of device (i.e. telescopic aids, deck-mounted remote video, etc.), a separate performance and cost-benefit rating system has been devised to rank the significant desirable and undesirable characteristics of that type of device. The factors are different for each type of device, and only factors for which there is variation between different devices of the same type are considered.

All factors are rated on a 10 to 0 scale, with 10 corresponding to the most desirable, and 0 to the least desirable. Some factors are weighted more heavily than others. The sum of the weighted scores for all factors is divided by the total weight, then this product is multiplied by 10 to provide a uniform 0 to 100 performance rating for each device.

Tables 1 through 6 present the performance rating systems used for various devices, and Table 7 presents the cost rating systems.

2.1.1 Discussion of Performance Ratings for Individual Categories

Hand-Held and Head-Mounted lights

- Carrying weight and size are considered to be very significant.

- Battery life ratings are based on an optimum battery life of 6 hours. Six hours would allow a light to be used continuously by an inspector during a typical inspection of a single large space, with a reasonable amount of reserve power. No battery replacement would be required during an inspection of a single space and the inspector would not have to carry extra batteries. It was felt that battery lives longer than 6 hours would require inspectors to carry unnecessary battery capacity, and thus unnecessary weight and bulk, with them while climbing and negotiating the difficult access conditions inside a large tankship cargo space. In terms of light output per unit weight, a lighting system which converts almost all of its battery capacity into light within the duration of a typical inspection of a single space is felt to be most efficient.

While a case can be made for additional battery capacity for emergencies, it is felt that an additional, smaller light is a more effective backup system than simply having additional battery capacity in the primary light, since the two-light system also allows for scenarios in which the primary light is lost or damaged, or in which its bulb burns out.

Deck-Based Lighting Equipment

- Bulb life is not included in these ratings because nearly all lights in these categories use standard halogen or xenon bulbs with similarly long lives. The lives of the bulbs used in fixed lights are much longer (hundreds or thousands of hours) than the lives of similar types of bulbs used in hand-carried, battery-powered lights, many of which have lives of only a few hours or tens of hours.

Telescopic Aids and Night-Vision Equipment

- These categories are rated separately, however, the same rating scale is used for both categories.

Deck-based and Remote Video equipment

- Since no off-the-shelf systems have been identified which are usable for marine inspection, no rating scale is presented for this equipment. However, several manufacturers are identified which manufacture or assemble video-based inspection systems which could be modified or adapted to marine inspection use.

## Table 1 Performance Rating Scales for Hand-Held Lights

| | Weight (oz) | Overall Size ($in^3$) | Battery Life (hours) | Battery Cost | Bulb Life (hours) | Bulb Cost | Intensity (candlepower) | Adjustable Beam | Durability | Total of Weighting Factors |
|---|---|---|---|---|---|---|---|---|---|---|
| Weighting Factor | 2 | 2 | 2 | .5 | 1 | .5 | 2 | 1 | 1 | 12.00 |
| Rating | | | | | | | | | | |
| 10 | 0-4 | 0-5 | 6 | <$.50 | >100 | <$2 | >100,000 | Yes | Very Durable | |
| 9 | 4-8 | 5-10 | | | | | | | | |
| 8 | 8-12 | 10-25 | 4, 9 | <$1.00 | 70-100 | <$4 | 50,000-100,000 | | | |
| 7 | 12-16 | 25-50 | | | | | | | | |
| 6 | 16-20 | 50-75 | 3, 15 | <$2.00 | 40-70 | <$8 | 20,000-50,000 | | Moderately Durable | |
| 5 | 20-24 | 75-100 | | | | | | | | |
| 4 | 24-30 | 100-150 | 2, 20 | <$4.00 | 30-40 | <$16 | 10,000-20,000 | | | |
| 3 | 30-36 | 150-200 | | | 20-30 | | | | | |
| 2 | 36-42 | 200-300 | 1, 30 | <$6.00 | | <$32 | 5,000-10,000 | | | |
| 1 | 42-48 | 300-400 | | | 10-20 | | | | | |
| 0 | >48 | >400 | <1, >30 | >$6.00 | <10 | <$64 | <5,000 | No | Fragile | |
| | | | | | | | | | | |

(APPENDIX A)

## Table 2 Performance Rating Scales for Head-Mounted Lights

| | Weight of Head Unit (oz) | Volume of Head Unit ($in^3$) | Total Weight (oz) | Overall Volume ($in^3$) | Battery Life (hours) | Battery Cost per 4-hr Use | Bulb Life (hours) | Bulb Cost | Intensity (cp) | Adjustable Beam | Durability | Total of Weighting Factors |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighting Factor | 2 | 2 | 2 | 2 | 2 | .5 | 1 | .5 | 2 | 1 | 1 | 16.00 |
| Rating | | | | | | | | | | | | |
| 10 | 0-2 | 0-4 | 0-4 | 0-5 | 6 | <$.50 | >100 | <$2 | >20,000 | Yes | Very Durable | |
| 9 | 2-4 | 4-8 | 4-8 | 5-10 | | | | | | | | |
| 8 | | 8-12 | 8-12 | 10-25 | 4, 9 | <$1.00 | 70-100 | <$4 | 15,000-20,000 | | | |
| 7 | 4-6 | 12-16 | 12-16 | 25-50 | | | | | | | | |
| 6 | | 16-20 | 16-20 | 50-75 | 3, 15 | <$2.00 | 40-70 | <$8 | 10,000-15,000 | | Moderately Durable | |
| 5 | 6-8 | 20-24 | 20-24 | 75-100 | | | | | | | | |
| 4 | | 24-28 | 24-30 | 100-150 | 2, 20 | <$4.00 | 30-40 | <$16 | 5,000-10,000 | | | |
| 3 | 8-12 | 28-32 | 30-36 | 150-200 | | | 20-30 | | | | | |
| 2 | | 32-36 | 36-42 | 200-300 | 1, 30 | <$6.00 | | <$32 | 2,500-5,000 | | | |
| 1 | 12-16 | 36-40 | 42-48 | 300-400 | | | 10-20 | | | | | |
| 0 | >16 | >40 | >48 | >400 | <1, >30 | >$6.00 | <10 | <$64 | <2,500 | No | Fragile | |
| | | | | | | | | | | | | |

(APPENDIX A)

## Table 3 Performance Rating Scales for Non-Self Contained 12V Hand-Held Lights

| | Intensity (candlepower) | Bulb Power (watts) | Weight (lb) | Adjustable Beam | Durability | Total of Weighting Factors |
|---|---|---|---|---|---|---|
| Weighting Factor | 2 | 2 | 2 | 1 | 1 | 8.00 |
| Rating | | | | | | |
| 10 | >1,000,000 | <50 | <1.5 | Yes | Very Durable | |
| 9 | 1,000,000 | | | | | |
| 8 | 900,000 | 50-70 | 1.5-2 | | | |
| 7 | 800,000 | | | | | |
| 6 | 700,000 | 70-100 | 2-2.5 | | Moderately Durable | |
| 5 | 600,000 | | | | | |
| 4 | 500,000 | 100-150 | 2.5-3 | | | |
| 3 | 400,000 | | | | | |
| 2 | 300,000 | | 3-3.5 | | | |
| 1 | 200,000 | | 3.5-4 | | | |
| 0 | <100,000 | >150 | >4 | No | Fragile | |
| | | | | | | |

(APPENDIX A)

**Table 4 Performance Rating Scales for Deck-Based Lighting Equipment**

| | Total Transport Weight (lb) | Largest Transport Dimension (inches) | Lighting Unit Weight (lb) | No. Setup Personnel Required | Setup Time (min) | Remote Aiming? | Light Intensity (watts) | Approved for Hazardous Locations? | Total of Weighting Factors |
|---|---|---|---|---|---|---|---|---|---|
| Weighting Factor | 1 | 1 | 2 | 1 | 1 | 1 | | 1 | 10.00 |
| Rating | | | | | | | | | |
| 10 | <10 | <12 | <5 | 1 | <5 | Yes | >2000 | Yes | |
| 9 | 10-20 | 12-18 | 5-10 | | | | | | |
| 8 | | 18-24 | 10-15 | | 5-10 | | 1500-2000 | | |
| 7 | 20-35 | 24-30 | 15-20 | | | | | | |
| 6 | | 30-36 | 20-25 | | 10-15 | | 1000-1500 | | |
| 5 | 35-50 | | 25-30 | 2 | | | | | |
| 4 | | 36-48 | 30-35 | | 15-20 | | 500-1000 | | |
| 3 | 50-65 | | 35-40 | | | | | | |
| 2 | | 48-72 | 40-45 | 3 | 20-30 | | 250-500 | | |
| 1 | 65-80 | | 45-50 | | | | | | |
| 0 | >80 | >72 | >50 | >3 | >30 | No | <250 | No | |
| | | | | | | | | | |

(APPENDIX A)

## Table 5 Performance Rating Scales for Telescopic Aids and Night-Vision Equipment

| | Weight (oz) | Size ($in^3$) | Magnification (unstabilized) | Magnification (stabilized) | Field of View at 100 ft (ft) | Training Time (hours) | Usable Lifetime (hours) | Durability | Approved or Intrinsically Safe? | Total of Weighting Factors |
|---|---|---|---|---|---|---|---|---|---|---|
| Weighting Factor | 2 | 2 | 2 | 2 | 1 | .5 | 1 | 1 | 1 | 12.50 |
| Rating | | | | | | | | | | |
| 10 | <6 oz | <5 | | >15 | >20 | <.25 | >10000 | Very Durable | Yes | |
| 9 | 4-8 | 5-10 | | 14-15 | | | | | | |
| 8 | 8-12 | 10-25 | | 12-13 | >16 | | 6000-10000 | | | |
| 7 | 12-16 | 25-50 | | 10-11 | | | | | | |
| 6 | 16-20 | 50-75 | | 8-9 | >12 | | 4000-6000 | | | |
| 5 | 20-24 | 75-100 | 6 | 6-7 | | <1 | | Moderately Durable | | |
| 4 | 24-30 | 100-150 | 5, 7 | 5 | >8 | | 2000-4000 | | | |
| 3 | 30-36 | 150-200 | 4, 8 | 4 | | | | | | |
| 2 | 36-42 | 200-300 | 3, 9 | 3 | >4 | | | | | |
| 1 | 42-48 | 300-400 | 2, >10 | 2 | | | | | | |
| 0 | >48 | >400 | 1 | 1 | <4 | >2 | <200 | Fragile | No | |
| | | | | | | | | | | |

(APPENDIX A)

**Table 6 Performance Rating Scales for Hand-Held Video Camcorders**

| | Weight (oz) | Volume ($in^3$) | Zoom Capability | Lowest Light Level (lux) | Stabilized Optics? | Training Time (hr) | Battery Life (hr) | Intrinsically Safe? | Total of Weighting Factors |
|---|---|---|---|---|---|---|---|---|---|
| Weighting Factor | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 10.00 |
| Rating | | | | | | | | | |
| 10 | 0-4 | 0-5 | ≥10x | <=1 | Yes | <.25 | >4 | Yes | |
| 9 | 4-8 | 5-10 | | 2 | | | | | |
| 8 | 8-12 | 10-25 | >8x | 3 | | | | | |
| 7 | 12-16 | 25-50 | | 4 | | | 3-4 | | |
| 6 | 16-20 | 50-75 | >6x | 5 | | | | | |
| 5 | 20-24 | 75-100 | | 6 | | <1 | | | |
| 4 | 24-30 | 100-150 | >4x | 7 | | | 2-3 | | |
| 3 | 30-36 | 150-200 | | 8 | | | | | |
| 2 | 36-42 | 200-300 | >2x | 9 | | <2 | | | |
| 1 | 42-48 | 300-400 | | 10 | | | 1-2 | | |
| 0 | >48 | >400 | 1x | >10 | No | >2 | <1 | No | |
| | | | | | | | | | |

(APPENDIX A)

## 2.2 Cost Ratings

Two cost rating schemes, both on a 1-to-12 scale with increasing cost, have been defined. One scale applies to hand-held and head-mounted lighting equipment, the other to all other categories of equipment. Table 7 describes the cost ratings.

**Table 7 Cost Ratings**

| Hand-Held and Head-Mounted Lights | | Other Equipment | |
|---|---|---|---|
| Rating | Cost | Rating | Cost |
| 1 | <$25 | 1 | <$50 |
| 2 | <$50 | 2 | <$100 |
| 3 | <$75 | 3 | <$250 |
| 4 | <$100 | 4 | <$500 |
| 5 | <$200 | 5 | <$1000 |
| 6 | <$400 | 6 | <$2000 |
| 7 | <$600 | 7 | <$4000 |
| 8 | <$800 | 8 | <$8000 |
| 9 | <$1000 | 9 | <$16,000 |
| 10 | <$1200 | 10 | <$32,000 |
| 11 | <$1400 | 11 | <$64,000 |
| 12 | >$1400 | 12 | >$64,000 |
| | | | |

## 2.3 Performance/Cost Ratio

An estimated benefit/cost ratio is obtained by dividing the 100-0 scale performance rating by the 1-12 scale cost rating, giving a 100-to-0 benefit/cost ratio scale, with 100 having the greatest benefit per unit cost, and 0 the least.

# 3 Lighting Equipment

As marine inspectors' workloads have increased, as rules against climbing in large spaces like tankship cargo spaces have come into effect, and as the use of access enhancements like staging has become increasingly expensive and time-consuming, the relative importance of the initial "screening" stage of the marine inspection has increased. During this stage, the inspectors' opportunities for close physical proximity to many elements of a vessel's structure are limited. Optimum lighting equipment is the key to improving the effectiveness of the screening stages of an inspection. The coverage, accuracy, and speed of simple visual inspection can be improved by better lighting equipment.

The lack of adequate portable lighting has also been a significant factor preventing wider acceptance of telescopic visual aids and remote video equipment by inspectors. In order for telescopic equipment to be used to its potential in the initial screening stages of an inspection, an intense spot of light must be projected to the distance at which the telescopic device is effective.

## 3.1 Discussion of Common Characteristics

The characteristics of virtually all lighting equipment are determined by the type of bulb used, by the control available over the beam pattern, and by the batteries.

### 3.1.1 Power and Energy Relationships

The fundamental unit of electrical quantity, or charge is the electron, which is a very small unit. One coulomb, which comprises $6.2 \times 10^{18}$ electrons, is a more manageable unit. Charge or quantity is denoted by the symbol **q**. The flowrate of charge is referred to as current; a flowrate of one coulomb per second is defined as one ampere, or one amp. The amount of charge which flows in one hour in a one-ampere current is referred to as one ampere-hour, which is also 3600 coulombs. Current is denoted by the symbol **i**.

Thus, **current**(amps) = **charge**(coulombs) / **time**(seconds) and

**charge**(amp-hours) = **current**(amps) x **time**(hours) .

In order for electrical currents to flow through materials, an electrical pressure, referred to as potential, or voltage, must be applied. Potentials are measured in units called Volts. The work done in moving a given charge through a resisting material is equal to the charge moved multiplied by the voltage applied. At any instant, the energy per unit time, or power, being expended in moving that charge against the resistance is the current multiplied by the applied voltage. Electrical power is generally measured in units of watts and electrical energy in units of watt-hours. One watt is the power consumed when an applied voltage of one volt moves a current of one ampere through a resisting material. One watt-hour of energy is expended when a one volt potential makes a one ampere current flow for one hour. If an applied potential of

two volts was required to move the same current, then two watt-hours of energy would be expended in the hour.

Thus, **Power**(watts) = **Potential**(volts) x **current**(amps) and

**Energy**(watt-hours) = **Power**(watts) x **time**(hours) .

In general, the energy expended in making electrical currents flow through material produces heat in the material. This heat raises the temperature, causing the material to radiate electromagnetic energy, which is spread across the spectrum from the infrared through the visible to the ultraviolet. Devices specifically designed for lighting purposes maximize the lighting efficiency of the electric current they consume, in other words, they emit a high percentage of their total emission of electromagnetic energy in the visible range.

The light intensity produced by a light increases as the power consumption of the light's bulb increases. Bulbs are generally rated by their power consumption in watts. A bulb which draws a current of two amperes at a voltage of 12 volts consumes 24 watts. It also radiates 24 watts of power; however, only a portion of the radiated energy is in the form of visible light. The proportion of visible light radiated to power consumed varies from one bulb type to another.

Batteries are rated by the amount of energy they contain. A 12-volt battery which can deliver 20 ampere-hours of charge contains 240 watt-hours of energy, while a 6-volt battery which can deliver 20 ampere-hours contains only half as much energy, or 120 watt-hours. As a general rule, the weight of batteries is proportional to their energy content; however, the ratio of energy content to weight varies greatly from one type of battery to another.

The general rules stated above determine the fundamental principles of operation of lighting equipment. The total amount of light energy which can be obtained from a light is a determined by the weight of its batteries. (The power consumption of the bulb (watts), multiplied by the burn time (hours) equals the battery's energy capacity (watt-hours)).

The intensity of the light is determined by the power consumption of the bulb. The light intensity of a given light can be changed by using a bulb with a different light output (which generally means a higher power consumption). Since the operating voltage is fixed by the design of the light, a change in the power consumption can only result from a change in the current drawn by the bulb. Increasing the power consumption (the bulb wattage) necessarily lowers the burn time if the battery capacity is not also increased.

### 3.1.2 Bulb type

A number of bulb types are available for portable lighting equipment. Until recently, conventional incandescent bulbs (PR series and equivalents) were standard in portable lights. These offer bulb lives of up to 45 hours, with relatively low light intensity and a yellowish light.

Krypton bulbs (PK series) are physically interchangeable with standard bulbs but provide higher intensity and whiter light. However, the increased intensity results in shorter battery life. Average bulb lifetimes are limited to about 15 hours.

Xenon flashtubes, until recently only used in strobe lights, have been adapted for continuous lighting, and are available in versions for hand-held battery powered lights. Xenon bulbs provide a white light similar to that of the Krypton bulbs with even higher light intensities. The Xenon bulbs used in hand-held lights have bulb lives of 20-40 hours; those used in larger deck-based systems have much longer lives. Xenon bulbs are much more expensive than standard or krypton bulbs, since the replaceable module includes electronic circuitry in addition to the bulb itself. Xenon modules are not presently available in standard configurations, so replacement modules must be purchased from the manufacturer of the light. In general, lights must be specifically designed to use xenon bulbs.

Halogen (quartz-iodide) bulbs are used in higher-voltage high-intensity lighting systems, and are also found in higher-capacity 12V hand lanterns which use battery packs or which are designed to plug into a separate 12V power source. (Modern automotive headlight systems usually use halogen bulbs.) Power requirements for halogen bulbs are at the limits of what is available in small self-contained battery-powered lights. Even with heavy battery packs, most high-intensity halogen-powered lights have operating times in the 1 hour range. Halogen bulbs have average lives ranging from about 50 hours for bulbs in the 30 to 100 watt range to several thousand hours for bulbs in the 1000 to 3000 watt range. Of all available bulbs, halogen is the most efficient, that is, it produces the greatest amount of visible light per unit energy consumption. Halogen bulbs for portable lights are generally not interchangeable with other types of bulbs, so lights are generally designed specifically to use these bulbs.

### 3.1.3 Beam Pattern

The requirements for lighting equipment in spaces such as tankship cargo spaces are difficult. The spaces are large, and the internal structure is dark, often rough in texture, and nonreflective. The light intensity available from hand-held lights is limited by the maximum allowable battery weight and the minimum allowable battery life. Especially when used in conjunction with telescopic devices, the beam pattern becomes critical. Too wide a beam will not project sufficient light to the range of the telescopic device. Too narrow a beam will make it difficult for an inspector to scan a large area in a reasonable amount of time and will make coordination of the aiming of the light and the telescopic device difficult. Since the lights alone, and the combination of lights and telescopic devices will be used to observe structure at various distances, an adjustable beam pattern is highly desirable.

### 3.1.4 Batteries

The performance of portable lights is highly dependent upon the type of batteries used. Batteries fall into two primary categories, disposable (or "primary") and rechargeable. The principal measures of battery performance are the weight (gravimetric) and volumetric energy

densities. Gravimetric energy density is measured in Watt-hours per unit weight, while volumetric energy density is measured in Watt-hours per unit volume. In this discussion, Wh/lb and $Wh/in^3$ will be used. Rechargeable batteries are economical, often having lives of 1000 charge cycles or more. However, in terms of energy densities, the best rechargeable batteries are far behind the most common disposable types.

Rechargeable Batteries

The most common types of rechargeable batteries are lead-acid and nickel-cadmium (NiCad). An improved technology, nickel/metal hydride (NiMH) is just now becoming available. Lead-acid batteries have optimum energy densities of about 15 Wh/lb and about 3 $Wh/in^3$. Nicad batteries are in the same range. NiMH batteries offer about a 60% improvement in energy density over NiCad and lead-acid batteries.

Disposable Batteries

The current standard disposable battery is the Alkaline/Manganese Dioxide cell ("Alkaline" or $Zn/MnO_2$). These have energy densities of 60 Wh/lb and 6 $Wh/in^3$. Lithium/Manganese Dioxide cells ("Lithium" or $Li/MnO_2$) have energy densities of 105 Wh/lb and 8 $Wh/in^3$. The latest technology in disposable batteries is Zinc-Air ($Zn/O_2$), which has energy densities of up to 140 Wh/lb and 19 $Wh/in^3$. Since Zinc/Air batteries use atmospheric oxygen as a cathode reactant, a much higher proportion of the total weight of the cell can be devoted to anode material, with correspondingly high energy densities.

Possibilities for Development

Neither lithium nor Zinc-Air batteries have yet seen extensive use in lighting equipment, although lithium cells are used in a few applications where their long shelf-life is an advantage. The need to supply zinc-air batteries with oxygen may prevent their use in some equipment which must be hermetically sealed. The construction of high-capacity packs from zinc-air batteries may also be difficult for the same reason - especially at high discharge rates, an ample supply of circulating air is needed. However, Zinc-air batteries are twice as efficient as alkaline cells in terms of weight and three times as efficient in terms of volume. By comparison to rechargeable batteries, they are as much as ten times as efficient, and for these reasons, they warrant further attention.

Marine inspectors face severe limitations on the weight and bulk of the tools they can carry, and their effectiveness is currently hampered by a lack of adequate lighting. A major advance in battery technology, even if expensive, might be cost-effective in the long run if it allowed inspectors to carry enough stored electrical energy to take advantage of new high intensity lighting technology, such as xenon and halogen bulbs. Higher light intensity, in turn, might allow inspectors to make better use of telescopic devices which could increase the effectiveness and efficiency of the screening phase of their inspections.

## 3.2 Hand-Held Lights

Hand-held lights are battery powered and range from penlight-type flashlights weighing a few ounces to large hand-held lanterns weighing several pounds. The most promising self-contained models use xenon bulbs and have plastic bodies. Larger halogen or xenon hand lanterns with belt-mounted battery packs are heavier but provide high light intensities. A separate category of 12V non-self-contained hand-held lights is included. These lights offer very high intensities but have large power requirements. They require a separate power source, and are generally designed to plug into a vehicle or vessel 12VDC power system, however, they can be powered by a portable battery pack if only non-continuous use is required.

Table 8 lists the hand-held lights surveyed and the specifications of those lights. Only lighting equipment which offered the potential of improvement over the present lights carried by inspectors is included. This excludes most "hardware-store" type flashlights. Table 9 shows performance and performance/cost ratings of these lights. Tables 12 and 13 are specifications for and ratings of 12V non-self-contained lights.

## 3.3 Head-Mounted Lights

Head-mounted lights generally provide lower intensities than hand-held lights, since most lights designed specifically for head-mounting are intended for use in constricted spaces such as mines. Larger-capacity head mounted lights use belt battery packs to minimize the weight of the head assembly. In addition, several smaller self-contained multi-purpose lights have been identified which can be adapted easily to head-mounted use.

The specifications and characteristics of the head-mounted lights surveyed are included in Table 10, and the performance and performance/cost ratings of these lights are included in Table 11.

## Table 8 Specifications for Hand-Held Lights

| Ref No. | Technology Category | Manufacturer | Model | Battery | Battery Life (hrs) | Recharge | Size | Weight (oz) | External Power (volts) | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Flashlight | Koehler | 100–D | Lead Acid | 1.75 | yes | 6" x 4" x 2" | 18 | 120 | $157.00 |
| 2 | Pocket Light | Kinetics | Q40 | 4AA | 3 | no | 5.6" x 1.5" x 1.1" | 8.6 | None | $24.00 |
| 3 | Penlight | Kinetic | UKE 2(AAA) | 2AAA | 3 | no | .75"D x 4.8" | 3.3 | None | $18.00 |
| 4 | Flashlight | Pelican | 2000C | 3C | 6.0 | no | 1.6"D x 7.50" | 14.5 | None | $28.60 |
| 5 | Flashlight | Dorcy | 41–3610 | 2D | 5.50 | no | 2.5"D x 7.75" | 19 | None | $12.00 |
| 6 | Flashlight | Pelican | 3500 | 4C | 6.0 | no | 2.5"D x 11.0" | 21 | None | $52.45 |
| 7 | Flashlight | Koehler | 8400T | 4C | 5.0 | no | 2.5"D x 6.30" | 26 | None | $32.55 |
| 8 | Flashlight | Koehler | 8400M | 4C | 5.0 | no | 2.5"D x 6.30" | 26 | None | $32.55 |
| 9 | Penlight | Pelican | 1900 | 2AAA | 7 | no | .625"D x 4.7" | 4.5 | None | $11.80 |
| 10 | Flashlight | Streamlight | SL–90X | Ni–Cad | 1.50 | yes | 2.25"D x 7.75" | 16 | 120 | $189.95 |
| 11 | Lanterns | Pelican | 4000 | 8D | 12.0 | no | 7.25" x 5" x 1.5" | 70 | None | $83.85 |
| 12 | Pocket Light | Bright Star | CV–8700 | 2AA | 7 | no | 1.5"D x 6" | 7 | None | $17.90 |
| 13 | Lanterns | Xenotech | MBS–450 | Ni–Cad | 1.0 | yes | 11" x 7.7" x 5.7" | 52 | 120 | $1,399.00 |
| 14 | Flashlight | Tekna | 2000 | 3Ni–Cad | 10.0 | yes | 1.6"D x 8.0" | 16 | 110 | $120.00 |
| 15 | Pocket Light | Streamlight | 71001 | 2AA | 7 | no | .675"D x 5.6" | 3.5 | None | $5.72 |
| 16 | Penlight | Fulton | 30 | 2AAA | 7 | no | .675"D x 5.5" | 3.3 | None | $5.72 |
| 17 | Penlight | Bright Star | 202 | 2AA | 7 | no | .675"D x 5.5" | 3.1 | None | $2.36 |
| 18 | Flashlight | Fulton | N35 | 2D | 19.2 | no | 2.25"D x 7.75" | 19 | None | $5.67 |
| 19 | Flashlight | Fulton | N44 | 2D | 19.2 | no | 2.25"D x 7.75" | 19 | None | $6.60 |
| 20 | Flashlight | Stewart Brown | F10X | 2D | 19.2 | no | 2.25"D x 7.75" | 19 | None | $5.30 |
| 21 | Flashlight | Fulton | 912 | 2D | 36.8 | no | 2.25"D x 7.75" | 19 | None | $4.89 |
| 22 | Flashlight | Bright Star | 2217 | 2D | 36.0 | no | 2.25"D x 7.75" | 18 | None | $9.52 |
| 23 | Flashlight | Boss | F120EXP | 2D | 19.2 | no | 2.5"D x 7.75" | 20 | None | $6.25 |
| 24 | Lanterns | Kinetics | UK1200 | 8D | 12 | no | 4.1" x 5" x 8" | 67 | None | $80.00 |
| 25 | Flashlight | Fulton | N33 | 3D | 35.0 | no | 2.25"D x 10.5" | 25 | None | $9.71 |
| 26 | Flashlight | Fulton | 933 | 3D | 35.0 | no | 2.25"D x 10.5" | 30 | None | $4.59 |
| 27 | Flashlight | Stewart Brown | F30X | 3D | 55.0 | no | 2.25"D x 10.5" | 26 | None | $6.65 |
| 28 | Flashlight | Streamlight | SL–2DX | 2D | 11.6 | no | 2.25"D x 10.5" | 26 | None | $32.95 |
| 29 | Lanterns | Mcdermott | A38 | Lead Acid | 1.0 | yes | 6.5" x 5.7" x 3" | 128 | 120 | $190.00 |
| 30 | Flashlight | Bright Star | 932–1B | 3D | 35.0 | no | 2.25"D x 10.5" | 28 | None | $5.79 |
| 31 | Lanterns | Koehler | 281–GB | Dry Cell | 8.0 | no | 8" x 7.7" x 4.7" | 48 | None | $144.00 |
| 32 | Flashlight | Fulton | 932 | 3D | 35.0 | no | 2.25"D x 10.5" | 32 | None | $5.79 |
| 33 | Flashlight | Boss | F130EXP | 3D | 35.0 | no | 2.5"D x 10.5" | 31 | None | $8.00 |
| 34 | Flashlight | Bright Star | 2224 | 3D | 35.0 | no | 2.25"D x 10.5" | 26 | None | $10.40 |
| 35 | Lanterns | TopLite | 9050 | Ni–Cad | 1.1 | yes | 15.7" x 7" x 7" | 159 | 240/120 | $560.00 |

(APPENDIX A)

**Table 8 (continued) Specifications for Hand-Held Lights**

| Ref No. | Bulb Type | Weather Proof | Shock Proof | Approved? | Candle–Power |
|---|---|---|---|---|---|
| 1 | Halogen | yes | yes | yes | 30000 |
| 2 | Xenon | yes | no | no | 6000 |
| 3 | Xenon | yes | no | no | 6000 |
| 4 | Xenon | yes | yes | yes | 12000 |
| 5 | Xenon | no | no | no | 5000 |
| 6 | Xenon | yes | yes | yes | 40000 |
| 7 | Halogen | yes | yes | yes | 25000 |
| 8 | Halogen | yes | yes | no | 25000 |
| 9 | Xenon | yes | yes | yes | 6000 |
| 10 | Halogen | yes | yes | yes | 15000 |
| 11 | Xenon | yes | yes | yes | 100000 |
| 12 | PR–4 | yes | no | no | 6000 |
| 13 | Xenon | yes | yes | no | 6000000 |
| 14 | K–2 | yes | yes | yes | 15000 |
| 15 | PR–4 | no | no | no | 2000 |
| 16 | 222 | no | no | no | 2000 |
| 17 | 222 | no | no | no | 2000 |
| 18 | PR–2 | yes | yes | yes | 10000 |
| 19 | PR–2 | yes | yes | yes | 10000 |
| 20 | PR–2 | yes | yes | yes | 10000 |
| 21 | PR–6 | yes | yes | yes | 5000 |
| 22 | PR–6 | yes | yes | yes | 5000 |
| 23 | PR–2 | yes | yes | yes | 10000 |
| 24 | Halogen | yes | no | no | 10000 |
| 25 | PR–3 | yes | yes | yes | 12000 |
| 26 | PR–3 | yes | yes | yes | 12000 |
| 27 | PR–3 | yes | yes | yes | 12000 |
| 28 | K–2 | no | no | no | 20000 |
| 29 | Halogen | yes | yes | no | 160000 |
| 30 | PR–3 | yes | yes | yes | 12000 |
| 31 | Xenon | yes | yes | yes | 25000 |
| 32 | PR–3 | yes | yes | yes | 12000 |
| 33 | PR–3 | yes | yes | yes | 12000 |
| 34 | PR–3 | yes | yes | yes | 7000 |
| 35 | Halogen | yes | yes | yes | 160000 |

(APPENDIX A)

**Table 8 (continued) Specifications for Hand-Held Lights**

| Ref No. | Technology Category | Manufacturer | Model | Battery | Battery Life (hrs) | Recharge | Size | Weight (oz) | External Power (volts) | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 36 | Flashlight | Streamlight | SL–3DX | 3D | 17.4 | no | 2.25"D x 13.0" | 31 | None | $33.95 |
| 37 | Flashlight | Fulton | 93K | 2D | 11.6 | no | 2.25"D x 7.75" | 18 | None | $4.84 |
| 38 | Flashlight | Fulton | 93 | 2D | 19.2 | no | 2.25"D x 7.75" | 18 | None | $4.89 |
| 39 | Flashlight | Bright Star | 2601 | 2D | 23.3 | no | 2.25"D x 7.75" | 18 | None | $4.80 |
| 40 | Flashlight | Streamlight | SL–5DX | 5D | 29.0 | no | 2.25"D x 17.5" | 42 | None | $35.95 |
| 41 | Flashlight | Fulton | 918N | 2D | 11.6 | no | 2.25"D x 7.75" | 18 | None | $2.77 |
| 42 | Flashlight | Fulton | 903 | 2D | 36.8 | no | 2.25"D x 7.75" | 19 | None | $3.21 |
| 43 | Flashlight | Fulton | 901 | 2D | 36.8 | no | 2.25"D x 7.75" | 19 | None | $2.81 |
| 44 | Lanterns | Collins | CD–12 | Lead Acid | 1.5 | yes | 11.7"x16.5"x5.5" | 200 | 120 | $875.00 |
| 45 | Lanterns | Collins | G46/2 | Lead Acid | 2.0 | yes | 13"x12"x5.5" | 78.4 | 120 | $185.00 |
| 46 | Lanterns | Collins | G56/5 | Lead Acid | 2.0 | yes | 13.5"x13.5"x5.5" | 126.4 | 120 | $215.00 |
| 47 | Lanterns | Bright Star | 3000 | Ni–Cad | 2.5 | yes | 9" x 9" x 5" | 31 | 6 | $66.00 |
| 48 | Lanterns | Mcdermott | EXAFL | Dry–Cell | 10.0 | no | 6.5" x 5.7" x 3" | 96 | None | $130.00 |
| 49 | Lanterns | Bright Star | 2206 | 2(C–Zn) | 10.0 | no | 8.5" x 5.5" x 3.5" | 40 | None | $11.20 |
| 50 | Flashlight | Koehler | 175 | Lead Acid | 12.0 | yes | 10" x 8" x 5.0" | 80 | 110 | $33.90 |
| 51 | Flashlight | Bright Star | 2625 | 3D | 35.0 | no | 2.25"D x 10.5" | 25 | None | $6.20 |
| 52 | Lanterns | Streamlight | 45131(8WS) | Ni–Cad | 10.0 | yes | 6.5" x 5.7" x 3" | 96 | 120 | $189.00 |
| 53 | Flashlight | Dorcy | 41–3610 | 2D | 9.0 | no | 2.5"D x 12.0" | 21 | None | $12.00 |
| 54 | Flashlight | Bright Star | 1925 | 3D | 35.0 | no | 2.25"D x 10.5" | 26 | None | $10.60 |
| 55 | Flashlight | Dorcy | 41–3630 | 5D | 12.0 | no | 2.5"D x 18.0" | 42 | None | $14.75 |
| 56 | Flashlight | Fulton | 930 | 3D | 35.0 | no | 2.25"D x 10.5" | 31 | None | $3.65 |
| 57 | Flashlight | Fulton | 934N | 3D | 15.0 | no | 2.25"D x 10.5" | 31 | None | $3.90 |
| 58 | Lanterns | Collins | G56/2 | Lead Acid | 1.0 | yes | 13.5"x12.5"x5.5" | 686.4 | 120 | $195.00 |
| 59 | Lanterns | Mcdermott | A35 | Lead Acid | 10.0 | yes | 6.5" x 5.7" x 3" | 96 | 120 | $140.00 |
| 60 | Flashlight | Brute | 3013k | 3D | 17.4 | no | 2.5"D x 10.5" | 31 | None | $2.97 |
| 61 | Lanterns | Bright Star | 2208 | 2(C–Zn) | 22.0 | no | 9" x 9" x 5" | 40 | None | $27.19 |
| 62 | Lanterns | Dorcy | 41–1098 | 4D | 15.0 | no | 10" x 8" x 8" | 48 | None | $8.00 |
| 63 | Lanterns | Fulton | 627 | C–Zn | 10.0 | no | 8.5" x 5.5" x 3.5" | 40 | None | $9.98 |

**Table 8 (continued) Specifications for Hand-Held Lights**

| Ref No. | Bulb Type | Weather Proof | Shock Proof | Approved? | Candle Power |
|---|---|---|---|---|---|
| 36 | K–2 | no | no | no | 20000 |
| 37 | K–2 | yes | no | no | 20000 |
| 38 | PR–2 | yes | yes | no | 10000 |
| 39 | PR–2 | no | no | no | 10000 |
| 40 | K–2 | no | no | no | 20000 |
| 41 | K–2 | no | yes | no | 15000 |
| 42 | PR–6 | no | yes | no | 5000 |
| 43 | PR–6 | no | yes | no | 5000 |
| 44 | Halogen | yes | no | no | 1000000 |
| 45 | PR–2 | yes | no | no | 200000 |
| 46 | PR–2 | yes | no | no | 400000 |
| 47 | K–2 | no | no | no | 35000 |
| 48 | PR–15 | yes | yes | no | 25000 |
| 49 | PR–13 | yes | yes | yes | 15000 |
| 50 | Xenon | yes | yes | yes | 15000 |
| 51 | PR–3 | no | no | no | 12000 |
| 52 | Halogen | yes | yes | no | 25000 |
| 53 | Xenon | no | no | no | 5000 |
| 54 | PR–7 | yes | yes | yes | 7000 |
| 55 | Xenon | no | no | no | 10000 |
| 56 | PR–3 | no | yes | no | 12000 |
| 57 | K–3 | no | yes | no | 15000 |
| 58 | PR–2 | yes | no | no | 400000 |
| 59 | Halogen | yes | yes | no | 25000 |
| 60 | K–2 | no | no | no | 15000 |
| 61 | PR–13 | yes | yes | yes | 20000 |
| 62 | Xenon | no | no | no | 50000 |
| 63 | PR–13 | yes | yes | no | 20000 |

## Table 9 Performance Ratings of Hand-Held Lights

| Ref No. | Technology Category | Manufacturer | Model | Weight | Overall Size | Battery Life | Battery Cost | Bulb Life | Bulb Cost | Intensity | Adjust Beam | Durability | Perf Rating | Cost | Perf/Cost Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Flashlight | Koehler | 100–D | 6 | 7 | 4 | 0 | 10 | 8 | 6 | 10 | 10 | 66.7 | 5 | 13.3 |
| 2 | Pocket Light | Kinetics | Q40 | 8 | 9 | 8 | 4 | 4 | 10 | 6 | 0 | 6 | 65.8 | 2 | 32.9 |
| 3 | Penlight | Kinetics | UKE2(AAA) | 10 | 10 | 8 | 4 | 4 | 10 | 2 | 0 | 6 | 64.2 | 1 | 64.2 |
| 4 | Flashlight | Pelican | 2000C | 7 | 8 | 9 | 4 | 4 | 10 | 4 | 0 | 10 | 64.2 | 2 | 32.1 |
| 5 | Flashlight | Dorcy | 41–3610 | 6 | 8 | 8 | 4 | 4 | 10 | 2 | 10 | 6 | 62.5 | 1 | 62.5 |
| 6 | Flashlight | Pelican | 3500 | 5 | 6 | 9 | 4 | 4 | 10 | 7 | 0 | 10 | 62.5 | 3 | 20.8 |
| 7 | Flashlight | Koehler | 8400T | 4 | 8 | 8 | 4 | 6 | 8 | 6 | 0 | 10 | 61.7 | 2 | 30.8 |
| 8 | Flashlight | Koehler | 8400M | 4 | 7 | 8 | 4 | 6 | 8 | 6 | 0 | 6 | 56.7 | 2 | 28.3 |
| 9 | Penlight | Pelican | 1900 | 9 | 10 | 2 | 4 | 4 | 10 | 2 | 0 | 6 | 52.5 | 1 | 52.5 |
| 10 | Flashlight | Streamlight | SL–90X | 7 | 7 | 2 | 0 | 6 | 8 | 4 | 0 | 10 | 50.0 | 5 | 10.0 |
| 11 | Lantern | Pelican | 4000 | 0 | 6 | 0 | 4 | 4 | 10 | 8 | 10 | 10 | 49.2 | 4 | 12.3 |
| 12 | Pocket Light | Bright Star | CV–8700 | 9 | 8 | 2 | 4 | 1 | 10 | 2 | 0 | 6 | 46.7 | 1 | 46.7 |
| 13 | Lantern | Xenotech | MBS–450 | 0 | 0 | 2 | 4 | 4 | 10 | 10 | 10 | 10 | 45.8 | 11 | 4.2 |
| 14 | Flashlight | Tekna | 2000 | 7 | 8 | 0 | 0 | 1 | 10 | 4 | 0 | 10 | 45.0 | 5 | 9.0 |
| 15 | Pocket Light | Streamlight | 71001 | 10 | 10 | 2 | 4 | 1 | 10 | 0 | 0 | 0 | 43.3 | 1 | 43.3 |
| 16 | Penlight | Fulton | 30 | 10 | 10 | 2 | 4 | 1 | 10 | 0 | 0 | 0 | 43.3 | 1 | 43.3 |
| 17 | Penlight | Bright Star | 202 | 10 | 10 | 2 | 4 | 1 | 10 | 0 | 0 | 0 | 43.3 | 1 | 43.3 |
| 18 | Flashlight | Fulton | N35 | 6 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 43.3 | 1 | 43.3 |
| 19 | Flashlight | Fulton | N44 | 6 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 43.3 | 1 | 43.3 |
| 20 | Flashlight | Stewart Brown | F10X | 6 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 43.3 | 1 | 43.3 |
| 21 | Flashlight | Fulton | 912 | 6 | 7 | 0 | 4 | 4 | 10 | 2 | 0 | 10 | 42.5 | 1 | 42.5 |
| 22 | Flashlight | Bright Star | 2217 | 6 | 7 | 0 | 4 | 4 | 10 | 2 | 0 | 10 | 42.5 | 1 | 42.5 |
| 23 | Flashlight | Boss | F120EXP | 6 | 7 | 0 | 4 | 1 | 8 | 4 | 0 | 10 | 42.5 | 1 | 42.5 |
| 24 | Lantern | Kinetics | UK1200 | 0 | 3 | 6 | 0 | 10 | 8 | 4 | 0 | 10 | 41.7 | 4 | 10.4 |
| 25 | Flashlight | Fulton | N33 | 4 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 40.0 | 1 | 40.0 |
| 26 | Flashlight | Fulton | 933 | 4 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 40.0 | 1 | 40.0 |
| 27 | Flashlight | Stewart Brown | F30X | 4 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 40.0 | 1 | 40.0 |
| 28 | Flashlight | Streamlight | SL–2DX | 4 | 7 | 0 | 4 | 1 | 10 | 4 | 10 | 0 | 40.0 | 1 | 40.0 |
| 29 | Lantern | Mcdermott | A38 | 0 | 4 | 2 | 0 | 6 | 8 | 10 | 0 | 6 | 40.0 | 5 | 8.0 |
| 30 | Flashlight | Bright Star | 932–1B | 4 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 40.0 | 1 | 40.0 |
| 31 | Lantern | Koehler | 281–GB | 1 | 2 | 0 | 0 | 4 | 10 | 6 | 10 | 10 | 39.2 | 5 | 7.8 |
| 32 | Flashlight | Fulton | 932 | 3 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 38.3 | 1 | 38.3 |
| 33 | Flashlight | Boss | F130EXP | 3 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 10 | 38.3 | 1 | 38.3 |
| 34 | Flashlight | Bright Star | 2224 | 4 | 7 | 0 | 4 | 1 | 10 | 2 | 0 | 10 | 36.7 | 1 | 36.7 |
| 35 | Lantern | TopLite | 9050 | 0 | 0 | 2 | 0 | 6 | 8 | 10 | 0 | 10 | 36.7 | 7 | 5.2 |

**Table 9 (continued) Performance Ratings of Hand-Held Lights**

| Ref No. | Technology Cat | Manufacturer | Model | Weight | Overal Size | Bat Life | Bat Cost | Bulb | Bulb Cost | Intensity | Adjust Beam | Durability | Perf Rating | Cost | Perf/Cost Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | Flashlight | Streamlight | SL–3DX | 3 | 6 | 0 | 4 | 1 | 10 | 4 | 10 | 0 | 36.7 | 1 | 36.7 |
| 37 | Flashlight | Fulton | 93K | 6 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 0 | 35.0 | 1 | 35.0 |
| 38 | Flashlight | Fulton | 93 | 6 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 0 | 35.0 | 1 | 35.0 |
| 39 | Flashlight | Bright Star | 2601 | 6 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 0 | 35.0 | 1 | 35.0 |
| 40 | Flashlight | Streamlight | SL–5DX | 2 | 6 | 0 | 4 | 1 | 10 | 4 | 10 | 0 | 35.0 | 1 | 35.0 |
| 41 | Flashlight | Fulton | 918N | 6 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 0 | 35.0 | 1 | 35.0 |
| 42 | Flashlight | Fulton | 903 | 6 | 7 | 0 | 4 | 4 | 10 | 2 | 0 | 0 | 34.2 | 1 | 34.2 |
| 43 | Flashlight | Fulton | 901 | 6 | 7 | 0 | 4 | 4 | 10 | 2 | 0 | 0 | 34.2 | 1 | 34.2 |
| 44 | Lantern | Collins | CD–12 | 0 | 0 | 2 | 0 | 6 | 8 | 10 | 0 | 6 | 33.3 | 9 | 3.7 |
| 45 | Lantern | Collins | G46/2 | 0 | 0 | 4 | 0 | 1 | 10 | 10 | 0 | 6 | 33.3 | 5 | 6.7 |
| 46 | Lantern | Collins | G56/5 | 0 | 0 | 4 | 0 | 1 | 10 | 10 | 0 | 6 | 33.3 | 6 | 5.6 |
| 47 | Lantern | Bright Star | 3000 | 3 | 0 | 5 | 0 | 1 | 10 | 6 | 0 | 6 | 33.3 | 3 | 11.1 |
| 48 | Lantern | Mcdermott | EXAFL | 0 | 4 | 0 | 0 | 6 | 8 | 6 | 0 | 10 | 33.3 | 5 | 6.7 |
| 49 | Lantern | Bright Star | 2206 | 2 | 3 | 0 | 4 | 4 | 10 | 4 | 0 | 10 | 32.5 | 1 | 32.5 |
| 50 | Flashlight | Koehler | 175 | 0 | 1 | 0 | 0 | 4 | 10 | 4 | 10 | 10 | 32.5 | 2 | 16.3 |
| 51 | Flashlight | Bright Star | 2625 | 4 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 0 | 31.7 | 1 | 31.7 |
| 52 | Lantern | Streamlight | 45131(8WS) | 0 | 4 | 0 | 4 | 6 | 8 | 6 | 0 | 6 | 31.7 | 5 | 6.3 |
| 53 | Flashlight | Dorcy | 41–3610 | 5 | 6 | 0 | 4 | 4 | 10 | 2 | 0 | 0 | 30.8 | 1 | 30.8 |
| 54 | Flashlight | Bright Star | 1925 | 4 | 7 | 0 | 4 | 4 | 10 | 2 | 0 | 0 | 30.8 | 1 | 30.8 |
| 55 | Flashlight | Dorcy | 41–3630 | 1 | 5 | 0 | 4 | 4 | 10 | 4 | 0 | 6 | 30.8 | 1 | 30.8 |
| 56 | Flashlight | Fulton | 930 | 3 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 0 | 30.0 | 1 | 30.0 |
| 57 | Flashlight | Fulton | 934N | 3 | 7 | 0 | 4 | 1 | 10 | 4 | 0 | 0 | 30.0 | 1 | 30.0 |
| 58 | Lantern | Collins | G56/2 | 0 | 0 | 2 | 0 | 1 | 10 | 10 | 0 | 6 | 30.0 | 5 | 6.0 |
| 59 | Lantern | Mcdermott | A35 | 0 | 4 | 0 | 0 | 6 | 8 | 6 | 0 | 6 | 30.0 | 5 | 6.0 |
| 60 | Flashlight | Brute | 3013k | 3 | 6 | 0 | 4 | 1 | 10 | 4 | 0 | 0 | 28.3 | 1 | 28.3 |
| 61 | Lantern | Bright Star | 2208 | 2 | 0 | 0 | 4 | 4 | 10 | 4 | 0 | 10 | 27.5 | 2 | 13.8 |
| 62 | Lantern | Dorcy | 41–1098 | 1 | 0 | 0 | 4 | 4 | 10 | 8 | 0 | 0 | 24.2 | 1 | 24.2 |
| 63 | Lantern | Fulton | 627 | 2 | 3 | 0 | 4 | 4 | 10 | 4 | 0 | 0 | 24.2 | 1 | 24.2 |

## Table 10 Specifications for Head-Mounted Lights

| Ref. No. | Manufacturer | Model | Batteries | Battery Life (hrs) | Recharge | Head Unit Size | Battery Pack Size | Total Weight (oz) | Total Volume (cu in) | Head Unit Weight (oz) | Head Unit Volume (cu in) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Streamlight | 300000 | 4AA | 4.5 | no | 7"x3"x2.2" | NA | 8 | 46 | 8 | 46 |
| 2 | Pelican | 2250 | 2AA | 7 | no | 3"x1.7"x1.6" | NA | 7 | 8.2 | 7 | 8.2 |
| 3 | MSA | 484823 | Lead Acid | 12 | yes | 3.2"D x 2.5" | 7.2"x5"x1.5" | 70 | 62 | 5 | 8 |
| 4 | Bright Star | 3550 | 3D | 15 | no | 2.5"D x 2" | 7"x5"x2" | 23 | 75 | 5 | 5 |
| 5 | Koehler | 5200–G7 | Lead Acid | 14 | yes | 3"D x 2.4" | 7.6"x5.5"x2.2" | 80 | 99 | 5 | 7 |
| 6 | Koehler | 5100–G7 | Lead Acid | 14 | yes | 3"D x 2.4" | 7.6"x5.5"x2.2" | 80 | 99 | 5 | 7 |
| 7 | REI | K410–150 | 4AA | 4.5 | no | 5"x3"x2.2" | NA | 8 | 33 | 8 | 33 |
| 8 | Bright Star | 8750 | 2C | 5 | no | 5"x3.5"x2" | NA | 6 | 35 | 6 | 35 |
| 9 | Fulton | 14KBV–CS | 2C | 5.5 | no | 5"x3"x2.2" | NA | 9 | 33 | 9 | 33 |
| 10 | Fulton | 14KBV–IB | 2C | 5.5 | no | 5"x3"x2.2" | NA | 9 | 33 | 9 | 33 |
| 11 | MSA | ML–2 | Lead Acid | 10 | yes | 3.2"D x 2.5" | 7.2"x5"x1.5" | 73 | 62 | 5 | 8 |
| 12 | BIRNS | ENERPAK | Lead Acid | .5 | yes | 3"D x 2.5" | 7.6"x4.8"x2.2" | 125 | 87 | 6 | 7 |
| 13 | Fulton | 6200–B | 3AA | 10 | no | 5"x3"x2.2" | NA | 8 | 33 | 8 | 33 |

**Table 10 (continued) Specifications for Head-Mounted Lights**

| Ref. No. | Cost | Bulb type | Weatherproof | Shockproof | Approved | Candlepower |
|---|---|---|---|---|---|---|
| 1 | $29.00 | K–2 | no | no | no | 5000 |
| 2 | $18.50 | Xenon | no | no | no | 6000 |
| 3 | $134.80 | Halogen | no | no | yes | 15000 |
| 4 | $9.70 | PR–3 | no | no | no | 12000 |
| 5 | $271.00 | Xenon | yes | yes | yes | 15000 |
| 6 | $302.00 | Xenon | yes | yes | yes | 15000 |
| 7 | $32.00 | K–2 | yes | yes | no | 5000 |
| 8 | $5.90 | K–2 | no | no | no | 10000 |
| 9 | $13.31 | K–2 | yes | yes | no | 17000 |
| 10 | $12.20 | K–2 | yes | yes | no | 17000 |
| 11 | $122.80 | K–2 | no | no | yes | 15000 |
| 12 | $989.55 | Halogen | yes | yes | no | 3100 |
| 13 | $8.64 | PR–7 | yes | yes | no | 4000 |

## Table 11 Performance Ratings of Head-Mounted Lights

| Ref. No. | Manufacturer | Model | Weight | Overall Size | Head Unit Weight | Head Unit Size | Bat. Life | Bat. Cost | Bulb Life | Bulb Cost | Intensity | Adjust. Beam | Durability | Perf. Rating | Cost | Perf/Cost Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Streamlight | 30000 | 9 | 7 | 5 | 0 | 10 | 4 | 1 | 10 | 4 | 10 | 6 | 58.8 | 2 | 29.4 |
| 2 | Pelican | 2250 | 9 | 9 | 5 | 8 | 2 | 4 | 4 | 10 | 4 | 0 | 6 | 56.9 | 1 | 56.9 |
| 3 | MSA | 484823 | 0 | 6 | 7 | 9 | 0 | 0 | 6 | 8 | 8 | 10 | 10 | 56.3 | 5 | 11.3 |
| 4 | Bright Star | 3550 | 5 | 6 | 7 | 9 | 4 | 4 | 1 | 10 | 6 | 0 | 6 | 55.0 | 1 | 55.0 |
| 5 | Koehler | 5200–G7 | 0 | 5 | 7 | 9 | 0 | 0 | 4 | 10 | 8 | 10 | 10 | 54.4 | 6 | 9.1 |
| 6 | Koehler | 5100–G7 | 0 | 5 | 7 | 9 | 0 | 0 | 4 | 10 | 8 | 10 | 10 | 54.4 | 6 | 9.1 |
| 7 | REI | K410–150 | 9 | 7 | 5 | 2 | 10 | 4 | 1 | 10 | 4 | 0 | 0 | 51.3 | 2 | 25.6 |
| 8 | Bright Star | 8750 | 9 | 7 | 3 | 2 | 8 | 2 | 1 | 6 | 6 | 0 | 6 | 50.6 | 1 | 50.6 |
| 9 | Fulton | 14KB–CS | 8 | 7 | 3 | 2 | 8 | 4 | 1 | 10 | 8 | 0 | 0 | 50.0 | 1 | 50.0 |
| 10 | Fulton | 14KB–IB | 8 | 7 | 3 | 2 | 8 | 4 | 1 | 10 | 8 | 0 | 0 | 50.0 | 1 | 50.0 |
| 11 | MSA | ML–2 | 0 | 6 | 7 | 9 | 0 | 0 | 1 | 10 | 8 | 0 | 10 | 47.5 | 5 | 9.5 |
| 12 | Birns | ENERPAK | 0 | 5 | 7 | 9 | 2 | 3 | 6 | 8 | 0 | 0 | 6 | 39.7 | 10 | 4.0 |
| 13 | Fulton | 6200–B | 9 | 7 | 5 | 2 | 0 | 4 | 4 | 10 | 2 | 0 | 0 | 38.1 | 1 | 38.1 |

(APPENDIX A)

## Table 12 Specifications for 12V Non-Self-Contained Hand-Held Lights

| Ref. No. | Manufacturer | Model | Intensity (cp) | Power (watts) | Bulb type | Bulb Life (hrs) | Weight (lbs) | Diameter (in) | Adjustable Beam? | Cost | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Collins | Pulsar | 1000000 | 55 | Halogen | 150 | 2.2 | 7.5 | No | $100 | Flood/Spot |
| 2 | Collins | CL–12 | 1000000 | 55 | Halogen | 150 | 3 | 7.1 | No | $187 | Flood/Spot |
| 3 | Collins | Magnum | 1500000 | 100 | Halogen | 100 | 3.8 | 8.5 | No | $220 | |
| 4 | Coleman | Night–Sight | 1000000 | 100 | Halogen | 100 | 3.5 | 8 | Yes | $35 | |
| 5 | Nite Tracker | XL 1000C | 1000000 | NA | Halogen | NA | 3.5 | 6.5 | No | $37 | |
| 6 | Brinkmann | Spot/Flood | 200000 | NA | NA | NA | 2.5 | NA | Yes | $33 | |
| 7 | Specialty | 2150 | 70000 | 38 | Halogen | NA | 2.5 | 4.5 | No | $78 | |
| 8 | Nite Tracker | RC 500K | 500000 | NA | Halogen | NA | 1.75 | 5.75 | No | $58 | Internal Rechg. Battery |
| 9 | Brinkmann | Max Million | 1000000 | NA | Halogen | NA | 5 | NA | No | $30 | |
| 10 | Specialty | 2150 | 100000 | 50 | Halogen | NA | 2.5 | 4.5 | No | $79 | |
| 11 | Brinkmann | Black Max | 400000 | NA | NA | NA | 2.5 | NA | No | $37 | |
| 12 | Brinkmann | Spot Lite | 200000 | NA | NA | NA | 2.5 | NA | No | $23 | |
| 13 | Specialty | 2129–505 | 160000 | 50 | Halogen | NA | 3 | 6.25 | No | $121 | Flood Bulb Available |
| 14 | Guest | Great White 233 | 200000 | 92 | NA | NA | 2.75 | 6.5 | Yes | $60 | |
| 15 | Brinkmann | Blue Max | 300000 | NA | NA | NA | 2.5 | NA | No | $33 | |
| 16 | Specialty | 2150 | 110000 | 100 | Tungsten | NA | 2.5 | 4.5 | No | $77 | |
| 17 | Nite Tracker | NT–450 | 450000 | NA | Tungsten sealed | NA | 1.75 | 5.75 | No | $30 | |
| 18 | Specialty | 2129–1 | 200000 | 100 | Tungsten | NA | 3 | 6.25 | No | $123 | Flood Bulb Available |
| 19 | Nite Tracker | SP–300 | 300000 | 150 | Tungsten sealed | NA | 1.75 | 5.75 | No | $26 | |
| 20 | Guest | Great White 231 | 200000 | 92 | NA | NA | 2.75 | 6.5 | No | $50 | |
| 21 | Guest | Great White 235 | 300000 | 150 | NA | NA | 2.75 | 6.5 | No | $58 | |

## Table 13 Performance Ratings of 12V Non-Self-Contained Lights

| Ref. No. | Manufacturer | Model | Intensity | Wattage | Weight | Adjustable Beam | Durability | Perf. Rating | Cost | Perf/Cost Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Collins | Pulsar | 10 | 8 | 6 | 0 | 6 | 56.3 | 5 | 11.3 |
| 2 | Collins | CL–12 | 10 | 8 | 4 | 0 | 6 | 53.8 | 5 | 10.8 |
| 3 | Collins | Magnum | 10 | 6 | 1 | 0 | 6 | 45.0 | 6 | 7.5 |
| 4 | Coleman | Night–Sight | 9 | 4 | 2 | 10 | 5 | 44.4 | 2 | 22.2 |
| 5 | Nite Tracker | XL 1000C | 9 | 6 | 2 | 0 | 5 | 43.1 | 2 | 21.6 |
| 6 | Brinkmann | Spot/Flood | 1 | 8 | 6 | 10 | 7 | 40.6 | 2 | 20.3 |
| 7 | Specialty | 2150–70 | 0 | 10 | 6 | 0 | 10 | 38.8 | 4 | 9.7 |
| 8 | Nite Tracker | RC 500K | 4 | 6 | 8 | 0 | 5 | 38.1 | 3 | 12.7 |
| 9 | Brinkmann | Max Million | 9 | 4 | 0 | 0 | 7 | 36.9 | 2 | 18.4 |
| 10 | Specialty | 2150–100 | 1 | 8 | 6 | 0 | 10 | 36.3 | 4 | 9.1 |
| 11 | Brinkmann | Black Max | 3 | 6 | 6 | 0 | 7 | 34.4 | 2 | 17.2 |
| 12 | Brinkmann | Spot Lite | 1 | 8 | 6 | 0 | 7 | 34.4 | 2 | 17.2 |
| 13 | Specialty | 2129–505 | 1 | 8 | 4 | 0 | 10 | 33.8 | 5 | 6.8 |
| 14 | Guest | Great White 233 | 1 | 6 | 4 | 10 | 6 | 32.5 | 3 | 10.8 |
| 15 | Brinkmann | Blue Max | 2 | 6 | 6 | 0 | 7 | 31.9 | 2 | 15.9 |
| 16 | Specialty | 2150–110 | 1 | 6 | 6 | 0 | 10 | 31.3 | 4 | 7.8 |
| 17 | Nite Tracker | NT–450 | 3 | 4 | 8 | 0 | 5 | 30.6 | 2 | 15.3 |
| 18 | Specialty | 2129–1 | 1 | 6 | 4 | 0 | 10 | 28.8 | 5 | 5.8 |
| 19 | Nite Tracker | SP–300 | 2 | 4 | 8 | 0 | 5 | 28.1 | 2 | 14.1 |
| 20 | Guest | Great White 231 | 1 | 6 | 4 | 0 | 6 | 26.3 | 2 | 13.1 |
| 21 | Guest | Great White 235 | 2 | 4 | 4 | 0 | 6 | 23.8 | 3 | 7.9 |

(APPENDIX A)

## 3.4 Deck-Based Lighting

Deck-based lighting systems are those which are not actually carried by inspectors as they move through a space. Deck-based lighting comprises spotlights and floodlights.

### 3.4.1 Discussion of Characteristics and Features

Floodlights

Floodlights have directional but wide beam pattern and are designed to illuminate a large area at a moderate intensity. Floodlight units are typically made up of one to four quartz light units, each using 500W or 1000W bulbs, and are mounted on low floor stands or on collapsible tripods.

The available floodlight units do not represent any great advances in lighting technology. Non-approved units from a number of manufacturers have almost identical specifications, and most use one, two, or four standard rectangular 500W quartz-halogen light modules. Most support structures are similar as well, either folding tripods or floor-type supports. Because of the weight of the lights themselves and of the long lengths of cord which would be necessary to use them in a large space on board ship, none of the available floodlight units are easily portable.

Most floodlights on the market are not rated for hazardous locations. However, at least one floodlight is available which is both shockproof and is approved for use in Class I, Division 1 hazardous locations. However, it is very heavy. Other, somewhat lighter units are available which have Class I, Division 2 approval. Approved floodlights must either be powered by 120VAC with Ground-Fault Current Interrupter (GFCI) protection or by low voltage (12V AC or DC or less).

The most likely application of floodlights in tankship inspections is to lower the lights to the bottom of a space and set them up there. During a typical inspection, they might be set up initially, then moved or re-aimed manually several times. Cord length and weight become significant factors when using floodlights in a large space. Because very heavy cords are required for the secondary side of low-voltage systems, 120VAC systems with GFCI protection are likely to be the most practical in situations requiring approved lighting equipment.

Spotlights

Spotlights have a sharply focused beam pattern and are designed to illuminate a relatively small area at a high intensity. Some spotlights have adjustable beam patterns and could serve as narrow-beam floodlights as well. During a typical inspection a spotlight would have to be aimed more or less continuously due to the small illuminated area. Spotlights use a single light source, generally xenon or halogen, with lenses to focus the beam pattern, and they generally

have cylindrical bodies. Most spotlights are designed for theater or concert use; none were identified that are safe for hazardous locations.

The most technically sophisticated spotlights are intended for outdoor use, but are not designed to take severe abuse. Because of the high wattages (1000-7000W), approval of spotlights for use in hazardous locations is not possible.

Three possible applications for spotlights are on deck, shining through a deck opening, hanging from deck through a deck opening, or mounted on a tripod or stand inside the space. In order for spotlights to be useful without requiring another person to operate them, they must be able to pan and tilt (and possibly change beam pattern) by remote control. Remote control units for spotlights are available, but can be more expensive than the lights themselves.

Only a few of the spotlight units available would fit through a tankship cargo space deck opening, and these are at the low-powered end of the range (1000 or 2000W), although 1000W is certainly a tremendous amount of light when concentrated into a spotlight beam. Because of the small size of the openings and the trunks around them, very little coverage of the inside structure could be obtained by shining a spotlight down through a deck opening. In addition, since the area on deck within a 10 ft radius of a cargo tank deck opening carries the same hazardous location classification as the space itself, placing a non-approved spotlight on deck to illuminate a space in which approved equipment is required would not be permitted.

### 3.4.2 Specifications and Performance Ratings

Tables 14 and 15 present specifications for and ratings of deck-based floodlights and spotlights.

### 3.4.3 Possibilities for Development

Virtually all spotlighting and floodlighting equipment is designed to be tripod or stand-mounted, an arrangement which does not lend itself well to inspections on tank vessels. The use of tripod and stand-mounted equipment requires not only the lights, but the mounts and the power supply cords to be lowered into a space through a small entry port to a surface which might be far from the entry point. Mounting lights in such a way that only the light head itself was lowered a short distance into a space through a deck access opening would be more practical in many cases.

The most fruitful area for development in fixed lighting equipment would be the design of a simple, lightweight support from which high-intensity lights could be hung in a deck access opening and which would allow aiming of the light. This would minimize the amount of power cord required, and would make it unnecessary to lower entire heavy lighting units far down into a space.

The underdeck structure is currently one of the most difficult areas for inspectors to gain access to, and a light lowered a short distance through a deck opening would be in close proximity these areas. This might provide sufficient illumination to allow inspectors at the bottom of the tank to use telescopic devices effectively in inspecting the underdeck structure without requiring heavy lighting equipment and long power cords to be lowered to the tank bottom, where it would be far from the area which requires illumination.

There is no lack of suitable lighting equipment for this purpose. Appropriate single or multiple lightweight AC powered halogen spot/flood units are available from a number of sources. Only the support and aiming mechanisms need development.

## Table 14 Specifications of Deck-Based Lights

| Ref. No. | Technology Cat. | Manufacturer | Model | Power (Watts) | Size | Weight (lbs) | External Power (volts) | Cost | Explosion Proof | Detect Flaws at Distance? | Training Req'd | Set-up Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tripod Floodlights** | | | | | | | | | | | | |
| 1 | Tripod Floods | Wanco | WT14-4Q | 2000 | 52"x28"x10" | 30 | 120 | $435 | no | no | <15min | <30min |
| 2 | Tripod Floods | Boss | T25Q1 | 1000 | 48"x24"12" | 45 | 120 | $400 | yes | no | <15min | <30min |
| 3 | Tripod Floods | Wanco | WT14-2Q | 1000 | 36"x28"10" | 22 | 120 | $350 | no | no | <15min | <30min |
| 4 | Tripod Floods | Specialty | 2174 | 1000 | 48"x24"x12" | 24 | 120 | $465 | no | no | <15min | <30min |
| 5 | Tripod Floods | Boss | GPT-15Q | 100 | 48"x12"12" | 30 | 120 | $210 | no | no | <15min | <30min |
| 6 | Tripod Floods | Boss | T45Q1 | 2000 | 48"12"x12" | 60 | 120 | $550 | no | no | <15min | <30min |
| 7 | Tripod Floods | Wanco | WT14-1Q | 500 | 28"x10"x10" | 16 | 120 | $275 | no | no | <15min | <30min |
| 8 | Tripod Floods | Boss | GPT-25Q | 500 | 48"x12"12" | 25 | 120 | $165 | no | no | <15min | <30min |
| 9 | Tripod Floods | Coleman | FS200Q | 1000 | 60"x24"x12" | 40 | 120 | $372 | no | no | <15min | <30min |
| 10 | Tripod Floods | Magnum | HL-500-2 | 1000 | 60"x24"x12" | 40 | 120 | $370 | no | no | <15min | <30min |
| 11 | Tripod Floods | Boss | PS400MH | 400 | 60"x24"x12" | 100 | 120 | $1,125 | no | no | <15min | <30min |
| **Floor Floodlights** | | | | | | | | | | | | |
| 1 | Portable Floods | Wanco | WSL-2Q | 1000 | 60"x36"x19" | 16 | 120 | $290 | no | no | <15min | <15min |
| 2 | Portable Floods | Boss | MT15Q | 1000 | 24"x24"18" | 15 | 120 | $120 | no | no | <15min | <15min |
| 3 | Portable Floods | Wanco | WSL-4Q | 2000 | 60"x36"x19" | 25 | 120 | $435 | no | no | <15min | <15min |
| 4 | Portable Floods | Wanco | WSL-1Q | 500 | 60"x28"19" | 7 | 120 | $145 | no | no | <15min | <15min |
| 5 | Portable Floods | Specialty | 2186 | 500 | 16"x12"x9" | 8.5 | 120 | $234 | no | no | <15min | <15min |
| 6 | Portable Floods | Boss | SG15Q | 500 | 24"x24"18" | 15 | 120 | $205 | no | no | <15min | <15min |
| 7 | Portable Floods | Specialty | 2140 | 100 | 9.5"DIAx9"x14" | 26 | 120 | $494 | no | no | <15min | <15min |
| 8 | Portable Floods | Boss | MT25Q | 500 | 24"x24"18" | 10 | 120 | $84 | no | no | <15min | <15min |
| **Spotlights** | | | | | | | | | | | | |
| 1 | Fixed Mount | Collins | FX-12 | 100 | 8.5"x7.1"x6" | 3.5 | 120 | $1,700 | no | yes | <15min | <15min |
| 2 | Theater Light | Safeguard | 1005 | 400 | 26"x8"x5" | 38 | 120 | $2,850 | no | yes | <15min | <30min |
| 3 | Theater Light | Xenotech | 4000 | 4000 | 24"x24"x24" | 75 | 120/220 | $16,995 | no | yes | <15min | <30min |
| 4 | Theater Light | Xenotech | 7000 | 7000 | 24"x24"x24" | 95 | 210/220 | $20,995 | no | yes | <15min | <30min |
| 5 | Theater Light | Phoebus | PSL-14/S/2K | 2000 | 17"x12"x11" | 52 | 120 | $9,680 | no | yes | <15min | <30min |
| 6 | Theater Light | Xenotech | 2000 | 2000 | 28"x24"x15" | 75 | 120/220 | $11,995 | no | yes | <15min | <30min |
| 7 | Theater Light | Phoebus | PSL-9/S/1K | 1000 | 17"x12"x11" | 52 | 120 | $8,030 | no | yes | <15min | <30min |

(APPENDIX A)

**Table 14 (continued) Specifications of Deck-Based Lights**

| Ref. No. | Bulb Type | Weather Proof | Shock Proof | Approved? |
|---|---|---|---|---|
| **Tripod Floodlights** | | | | |
| 1 | Quartz | yes | no | no |
| 2 | Quartz | yes | no | no |
| 3 | Quartz | yes | no | no |
| 4 | Quartz | yes | no | no |
| 5 | Quartz | yes | no | no |
| 6 | Quartz | yes | no | no |
| 7 | Quartz | yes | no | no |
| 8 | Quartz | yes | no | no |
| 9 | Halogen | yes | no | no |
| 10 | Halogen | yes | no | no |
| 11 | Halide | yes | yes | yes |
| **Floor Floodlights** | | | | |
| 1 | Quartz | yes | no | no |
| 2 | Quartz | yes | no | no |
| 3 | Quartz | yes | no | no |
| 4 | Quartz | yes | no | no |
| 5 | Quartz | yes | no | no |
| 6 | Quartz | yes | no | no |
| 7 | Quartz | yes | yes | yes |
| 8 | Quartz | yes | no | no |
| **Spotlights** | | | | |
| 1 | Halogen | yes | no | no |
| 2 | Halide | yes | no | no |
| 3 | Xenon | yes | no | no |
| 4 | Xenon | yes | no | no |
| 5 | Xenon | yes | no | no |
| 6 | Xenon | yes | no | no |
| 7 | Xenon | yes | no | no |

## Table 15 Performance Ratings of Deck-Based Lights

| Ref. No. | Technology Cat. | Manu-facturer | Model | Total Transport Weight | Largest Transport Dimension | Weight | No. of Set up Personnel Req'd | Set up Time | Intensity | Approved | Perf Rating | Cost | Perf/Cost Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tripod Floodlights** | | | | | | | | | | | | | |
| 1 | Tripod Floods | Wanco | WSL-10-4C | 4 | 4 | 5 | 5 | 4 | 8 | 0 | 43 | 4 | 10.8 |
| 2 | Tripod Floods | Boss | T25Q1 | 5 | 4 | 6 | 5 | 4 | 6 | 0 | 42 | 4 | 10.5 |
| 3 | Tripod Floods | Wanco | WSL-10-2C | 4 | 4 | 6 | 5 | 4 | 6 | 0 | 41 | 4 | 10.3 |
| 4 | Tripod Floods | Specialty | 2174 | 3 | 4 | 6 | 5 | 4 | 6 | 0 | 40 | 4 | 10.0 |
| 5 | Tripod Floods | Boss | GPT-15Q | 4 | 4 | 5 | 5 | 4 | 6 | 0 | 39 | 3 | 13.0 |
| 6 | Tripod Floods | Boss | T45Q1 | 5 | 4 | 2 | 5 | 4 | 8 | 0 | 38 | 5 | 7.6 |
| 7 | Tripod Floods | Wanco | WSL-10-1C | 4 | 4 | 8 | 5 | 4 | 2 | 0 | 37 | 4 | 9.3 |
| 8 | Tripod Floods | Boss | GPT-25Q | 5 | 4 | 6 | 5 | 4 | 2 | 0 | 34 | 3 | 11.3 |
| 9 | Tripod Floods | Coleman | FS200Q | 2 | 2 | 3 | 5 | 4 | 6 | 0 | 31 | 4 | 7.8 |
| 10 | Tripod Floods | Magnum | HL-500-2 | 2 | 2 | 3 | 5 | 4 | 6 | 0 | 31 | 4 | 7.8 |
| 11 | Tripod Floods | Boss | PS400MH | 0 | 4 | 0 | 5 | 4 | 2 | 10 | 27 | 6 | 4.5 |
| **Floor Floodlights** | | | | | | | | | | | | | |
| 1 | Portable Floods | Wanco | WSL-2Q | 8 | 7 | 9 | 10 | 10 | 6 | 0 | 65 | 4 | 16.3 |
| 2 | Portable Floods | Boss | MT15Q | 7 | 8 | 8 | 10 | 10 | 6 | 0 | 63 | 3 | 21.0 |
| 3 | Portable Floods | Wanco | WSL-4Q | 6 | 7 | 7 | 10 | 10 | 8 | 0 | 63 | 4 | 15.8 |
| 4 | Portable Floods | Wanco | WSL-1Q | 9 | 7 | 10 | 10 | 10 | 2 | 0 | 60 | 3 | 20.0 |
| 5 | Portable Floods | Specialty | 2186 | 8 | 9 | 9 | 10 | 10 | 2 | 0 | 59 | 3 | 19.7 |
| 6 | Portable Floods | Boss | SG15Q | 7 | 8 | 8 | 10 | 10 | 2 | 0 | 55 | 3 | 18.3 |
| 7 | Portable Floods | Specialty | 2140 | 4 | 9 | 5 | 10 | 10 | 0 | 10 | 53 | 4 | 13.3 |
| 8 | Portable Floods | Boss | MT25Q | 5 | 8 | 6 | 10 | 10 | 2 | 0 | 49 | 3 | 16.3 |
| **Spotlights** | | | | | | | | | | | | | |
| 1 | Fixed Mounts | Collins | FX-12 | 10 | 10 | 10 | 5 | 4 | 0 | 0 | 49 | 6 | 8.2 |
| 2 | Theater Light | Safeguard | 1005 | 6 | 9 | 7 | 5 | 2 | 2 | 0 | 40 | 9 | 4.4 |
| 3 | Theater Light | Xenotech | 4000 | 0 | 8 | 0 | 5 | 2 | 10 | 0 | 35 | 10 | 3.5 |
| 4 | Theater Light | Xenotech | 7000 | 0 | 8 | 0 | 5 | 2 | 10 | 0 | 35 | 10 | 3.5 |
| 5 | Theater Light | Phoebus | PSL-14/S/2K | 0 | 9 | 0 | 5 | 2 | 8 | 0 | 32 | 9 | 3.6 |
| 6 | Theater Light | Xenotech | 2000 | 0 | 8 | 0 | 5 | 2 | 8 | 0 | 31 | 9 | 3.4 |
| 7 | Theater Light | Phoebus | PSL-9/S/1K | 0 | 9 | 0 | 5 | 2 | 6 | 0 | 28 | 9 | 3.1 |

(APPENDIX A)

## 4 Telescopic Aids

Magnification devices which might be of use to inspectors include both fixed-optic and stabilized-optic monoculars and binoculars. However, up until now, a surprisingly small percentage of marine inspectors have used telescopic aids. The primary obstacles to inspector acceptance and use of telescopic aids have been price, fragility, weight and bulk, the need for high-intensity lighting equipment to project light out to the range of the magnification device, and the difficulty in coordinating the aiming of both a telescopic device and a highly directional light source.

### 4.1 Discussion of Characteristics and Features

The light-gathering ability, weight, magnification, objective diameter, and field of view are interrelated quantities for magnification devices. The light-gathering ability of magnification devices increases with objective diameter but decreases with magnification. 7x50 binoculars are slightly brighter (they have higher light-gathering ability) than the naked eye, while 6x35 binoculars are slightly darker than the naked eye. The better the light-gathering ability, the lower the need for external illumination.

Weight increases with both objective diameter and magnification, and field of view decreases with increasing magnification but increases slightly with objective diameter.

Standard fixed-optic binoculars and monoculars are useful as hand-held devices up to magnifications of about 7x. The combination of the added weight and the magnification of vibrations renders devices with magnifications much beyond 7x less effective when hand-held.

Extremely light (4 oz) 8x fixed-optic monoculars are available for less than $100. Marine-grade 7x50 fixed-optic binoculars weigh in the 1.5-2.5 lb range and cost $200-400. 6x35 binoculars are lighter and somewhat less expensive than 7x50s but have less light-gathering ability than 7x50, and thus require more intense lighting.

The problem of magnified vibrations in hand-held devices can be mitigated by the use of stabilization, with an order of magnitude increase in cost and a considerable increase in weight. Stabilized devices are typically available up to 14X. Passively stabilized monoculars up to 10X with weights of 21 oz are available in the $1000-1500 range. Stabilized binoculars use an active gyroscopic stabilization system; they are available up to 14x, weighing about 72 oz, and costing $4500-6000. Stabilized binoculars can also be equipped with night-vision devices.

In addition to vibration, another difficulty with using any kind of magnification device during an inspection is the requirement for a separate high-intensity light source. In order to utilize the capabilities of magnification to the fullest, the light source must be able to project light out to the useful range of the magnification device. This requires lighting equipment which is more sophisticated, and generally heavier than, a standard flashlight. It is difficult for one

person to coordinate the aiming of a hand-held magnification device and a heavy hand-held light source. The use of image-intensification (night-vision) devices is one possible solution to this problem.

## 4.2 Specifications and Performance Ratings

Specifications and of Telescopic Aids are presented in Table 16. Performance and performance/cost ratings are contained in Table 17.

## 4.3 Possibilities for Development

Development of telescopic equipment is costly, and should only be considered if field testing of existing equipment identifies a specific unfulfilled need in this area. Existing devices cover a wide range of sizes, weights, magnifications, and stabilization options. Unless a modification to existing equipment is widely recommended by the inspectors, and unless inspectors would use and benefit from an device specially enhanced to meet their needs, no development is recommended.

## 5 Night-Vision Equipment

Night-vision equipment uses electronic image intensifier tubes (silicon intensified target, or SIT) to amplify light emitted by objects to a visible level. These tubes can be incorporated into goggles, telescopic visual aids, or video equipment. The images produced by all current night-vision equipment are a greenish monochrome. Some types of intensifiers produce a visible output in response to infrared as well as to visible light, a feature which is not likely to be of value to marine inspectors, and might lead to confusion.

### 5.1 Discussion of Characteristics and Features

The principal advantage of night-vision to inspectors would be obtained in combination with magnification devices. A magnified night-vision scope or binoculars would eliminate the need for high-intensity lighting equipment needed to project light to the distant objects which could be inspected with magnifying devices. The problem of aiming a portable light source and a magnification device at the same time would therefore be eliminated. However, the monochrome nature of the image and the low image resolution inherent in image-intensification systems might limit the effectiveness of such devices.

It is not likely that night vision devices without magnification would be of much use to inspectors. Considering the monochrome image and limitations on resolution, unmagnified night-vision scopes or goggles would provide no significant improvement in close-range low-light visual inspection over the simple hand-carried flashlight.

Types of night-vision equipment

- Head-mounted night-vision goggles

  These units generally use one intensifier tube with two eyepieces, and do not have magnification. The typical goggles are bulky and attach to a persons head or hardhat. More sophisticated versions are becoming available which are much smaller and lighter, and which can flip down into the user's view from a helmet visor.

- Night-vision monoculars and binoculars

  These combine magnification with image intensification. In the higher magnification ranges, stabilized optics are available. The less expensive binocular devices use one intensifier tube with two eyepieces, the more expensive versions use two intensifiers. Most magnified night-vision equipment is available in stabilized versions to allow magnifications up to 14x.

- Intensified video equipment.

  Silicon-Intensified Target (SIT) intensifiers (similar to those in night-vision equipment) have been incorporated into video cameras. They increase the usable sensitivity of the camera to about $10^{-5}$ lux ($10^{-6}$ footcandles), but with a monochrome image. Normal Charge-Coupled Device (CCD) color cameras have sensitivities down to about 1 lux. A new type of intensification, Intensified CCD, or ICCD, is now being used in video equipment. This technology also produces monochrome images, and sensitivity levels are similar to SIT devices, but the intensification components are lighter and smaller, making ICCD better suited to miniaturized video cameras.

Image intensifier technology

The performance and operating characteristics of night-vision equipment are determined primarily by the technology behind the SIT image intensifier tubes. There are three classes of SIT tubes, referred to as Generation II (Gen2), Generation II Plus (Gen2.5) and Generation III (Gen3). Costs increase with the generation number. The light amplification factors of devices using Gen2, Gen 2.5, and Gen3 are typically 800, 1700, and 2000, respectively. Resolution is 25, 30, and 36 line pairs/mm, respectively. The sensitivity of Gen3 tubes peaks in the near-infrared spectrum, dropping to nearly zero at the middle of the visible spectrum, while that of the Gen2 and Gen2.5 tubes peaks in the visible range and is actually higher than that of the Gen3 tubes over the lower 2/3 of the visible range. These response characteristics make Gen3 equipment well suited to observing heat-emitting objects like people and vehicles. It is not clear if Gen3 offers any advantage over Gen2 and Gen2.5 for marine inspection purposes; a comparative test in the field would be the best way to evaluate the difference.

The performance of intensifier tubes degrades irreversibly with use. The usable lifetime of the tubes is 2000, 4000, and 7500 hours for Gen2, Gen2.5, and Gen3, respectively. Except for devices using gyroscopically stabilized optics, the cost of the intensifier tube or tubes represents the largest portion of the total cost of the device. Therefore, tube renewal costs are a significant fraction of the total replacement cost of the device.

Exposure to bright lights can quickly burn out the phosphor screen of an intensifier, making replacement necessary. Most devices are protected against brief flashes in an otherwise dark environment, but exposure to sunlight or a bright light for more than a brief period will burn out the screen.

## 5.2 Specifications and Performance Ratings

Specifications of night-vision equipment are included in Table 16, along with, but separated from the specifications for telescopic aids. Performance and performance/cost ratings for night-vision equipment are included in Table 17.

## Table 16 Specifications for Telescopic Aids and Night-Vision Equipment

| Ref. No. | (Day/ Night) | Technology Cat. | Night Vision | Day Vision | Stabil– ized | Manufacturer | Model | Magnification | Field of View @ 100 ft (ft) | Size (l x w x h) |
|---|---|---|---|---|---|---|---|---|---|---|
| Telescopic Aids | | | | | | | | | | |
| 1 | (D) | Monocular Hand Held | no | yes | yes | FV | MK111P | 10X | 12.4 | 6.5" x 3.25" x 2.87" |
| 2 | (D) | Monocular Hand Held | no | yes | no | UNITRON | 118C | 8X | 15.7 | 2.5" x 1.5" x 1.75" |
| 3 | (D) | Monocular Hand Held | no | yes | no | UNITRON | 119B | 10X | 12.2 | 5" x 1.5" x 1.75" |
| 4 | (D) | Monocular Hand Held | no | yes | yes | FV | MK111m | 8X | 17.5 | 5.85" x 3.25" x 2.87" |
| 5 | (D) | Binocular Hand Held | no | yes | no | UNITRON | 111A | 7X | 11.3 | 7" x 5" x 2" |
| 6 | (D) | Binocular Hand Held | no | yes | yes | FV | MK X | 10X & 14X | 8.7 | 8" x 7" x 3.78" |
| 7 | (D) | Binocular Hand Held | no | yes | yes | ILS | S1040D | 10X & 14X | 8.7 | 7.9" x 7" x 3.7" |
| 8 | (D) | Binocular Hand Held | no | yes | no | UNITRON | 111B | 8X | 14.0 | 5" x 4.5" x 1.75" |
| 9 | (D) | Binocular Hand Held | no | yes | no | UNITRON | 107BS | 7X | 12.0 | 8" x 5" x 2.5" |
| 10 | (D) | Binocular Hand Held | no | yes | no | UNITRON | 111C | 10X | 11.4 | 7" x 5" x 2" |
| 11 | (D) | Binocular Hand Held | no | yes | no | UNITRON | 125B | 10X–22X | 5.2 | 7" x 5" x 2.5" |
| Night Vision | | | | | | | | | | |
| 1 | (N) | Monocular Hand Held | yes | no | no | EEV | P2000 | 1X | 57.3 | 4.7" x 1.8" x 1.8" |
| 2 | (N) | Pocket Scope | yes | no | no | NVEC | NVEC 520A GENII | 2X | 31.6 | 5.5" x 2" x 3.5" |
| 3 | (N) | Pocket Scope | yes | no | no | SDS | VNVA–311 GENII | 1X | 72.7 | 4.6" x 2.5" x 2.9" |
| 4 | (N) | Pocket Scope | yes | no | no | NVEC | NVEC 600A GENIII | 2X | 31.6 | 5.5" x 2" x 3.5" |
| 5 | (N) | Pocket Scope | yes | no | no | SDS | VNVA–311 GENIII | 1X | 72.7 | 4.6" x 2.5" x 2.9" |
| 6 | (D/N) | Binocular Hand Held | yes | yes | yes | FV | MK–Vn | 8.4XN/15XD | 8.0 | 10.3" x 6.4" x 3" |
| 7 | (N) | Binocular Hand Held | yes | no | no | Moonlight | MPN 30K | 2.5X | 32 | 8"x5.5"x3.6" |
| 8 | (N) | Monocular Hand Held | yes | no | no | Moonlight | MPN 1500 | 2.3X | 32 | 7.3"x9.6"x2.6" |
| 9 | (N) | Monocular Head Mounted | yes | no | no | SDS | PVS–7B GENII | 1X | 72.7 | 6" x 6.1" x 4" |
| 10 | (N) | Monocular Head Mounted | yes | no | no | NVEC | 1500–4 GENIII | 1X | 72.7 | 6" x 6.1" x 4" |
| 11 | (N) | Monocular Head Mounted | yes | no | no | NVEC | 1500–3 GENII | 1X | 72.7 | 6" x 6.1" x 4" |
| 12 | (N) | Monocular Head Mounted | yes | no | no | SDS | PVS–7B GENIII | 1X | 72.7 | 6" x 6.1" x 4" |
| 13 | (N) | Binocular Head Mounted | yes | no | no | ILS | PVS–5 GENII | 1X | 72.7 | 6" x 5.5" x 4.5" |
| 14 | (N) | Binocular Head Mounted | yes | no | no | ILS | PVS–7 GENIII | 5X | 15.3 | 6" x 6.1" x 4" |
| 15 | (N) | Binocular Head Mounted | yes | no | no | SDS | GENII | 1X | 72.7 | 6.8" x 6.1" x 4.7" |
| 16 | (N) | Binocular Head Mounted | yes | no | no | SDS | GENIII | 1X | 72.7 | 6.8" x 6.5" x 4.7" |
| 17 | (D/N) | Binocular Hand Held | yes | yes | yes | ILS | S1040D/N GEN2.5 | 10X | 8.7 | 7.9" x 7" x 3.7" |
| 18 | (D/N) | Binocular Hand Held | yes | yes | yes | ILS | S1040D/N GEN3 | 10X | 8.7 | 7.9" x 7" x 3.7" |
| 19 | (N) | Monocular Hand Held | yes | no | no | Moonlight | MPN 60K | 5.2X | 15.3 | 11"x4.0"x3.5" |
| 20 | (N) | Binocular Head Mounted | yes | no | no | NVEC | NVEC 800HP | 1X | 72.7 | 6.7" x 6.7" x 4.7" |
| 21 | (N) | Binocular Head Mounted | yes | no | no | NVEC | NVEC 800 | 1X | 72.7 | 6.7" x 6.7" x 4.7" |

## Table 16 (continued) Specifications for Telescopic Aids and Night-Vision Equipment

| Ref. No. | Weight (oz) | External Power (vdc) | Battery | Battery Life (hr) | Cost | Approved? | Detect Flaws From Distance? | Training Req'd |
|---|---|---|---|---|---|---|---|---|
| **Telescopic Aids** | | | | | | | | |
| 1 | 21 | n/a | n/a | n/a | $1,200 | yes | yes | none |
| 2 | 3.9 | n/a | n/a | n/a | $78 | yes | yes | none |
| 3 | 4.3 | n/a | n/a | n/a | $88 | yes | yes | none |
| 4 | 21 | n/a | n/a | n/a | $1,500 | yes | yes | none |
| 5 | 22 | n/a | n/a | n/a | $285 | yes | yes | none |
| 6 | 70.4 | 6 to 30 | 2AA | 40 | $4,440 | no | yes | <15 min |
| 7 | 74 | 12 to 28 | 6AA | 120 | $5,795 | no | yes | <15 min |
| 8 | 16 | n/a | n/a | n/a | $285 | yes | yes | none |
| 9 | 30 | n/a | n/a | n/a | $175 | yes | yes | none |
| 10 | 22 | n/a | n/a | n/a | $305 | yes | yes | none |
| 11 | 32.4 | n/a | n/a | n/a | $250 | yes | yes | none |
| **Night Vision** | | | | | | | | |
| 1 | 11.4 | 2.5 to 3.5 | 3AA | 30 | $2,995 | no | no | <15 min |
| 2 | 19 | 3 | 2AA | 40 | $3,995 | no | yes | <15 min |
| 3 | 12.3 | 1.5 | 2AA | 40 | $3,995 | no | no | <15 min |
| 4 | 19 | 3 | 2AA | 40 | $5,795 | no | yes | <15 min |
| 5 | 12.31 | 1.5 | 2AA | 40 | $6,250 | no | no | <15 min |
| 6 | 70.5 | 2.7 to 3 | 2C | 40 | $4,240 | no | yes | <15 min |
| 7 | 40.5 | n/a | 2AA | 40 | $849 | no | no | <15 min |
| 8 | 15.1 | n/a | 2AA | 40 | $4,549 | no | no | <15 min |
| 6 | 24 | 2.7 to 3 | 2AA | 20 | $3,847 | no | no | <15 min |
| 7 | 24 | 2.7 to 3 | 2AA | 50 | $3,599 | no | no | <15 min |
| 11 | 24 | 2.7 to 3 | 2AA | 50 | $3,099 | no | no | <15 min |
| 12 | 24 | 2.5 to 3.5 | 2AA | 20 | $5,992 | no | no | <15 min |
| 13 | 30.4 | 2.7 to 3 | 2AA | 40 | $7,610 | no | no | <15 min |
| 14 | 40 | 14 to 28 | 2AA | 40 | $6,946 | no | yes | <15 min |
| 15 | 30 | 2 to 3.5 | 2AA | 20 | $5,300 | no | no | <15 min |
| 16 | 30 | 2 to 3.5 | 2AA | 20 | $6,600 | no | no | <15 min |
| 17 | 74 | 12 to 28 | 6AA | 120 | $24,795 | no | yes | <15 min |
| 18 | 74 | 12 to 28 | 6AA | 120 | $44,795 | no | yes | <15 min |
| 19 | 75.2 | n/a | 1–9V | 40 | $1,099 | no | no | <15 min |
| 20 | 33.6 | 3 vdc | 2AA | 40 | $5,599 | no | no | <15 min |
| 21 | 33.6 | 3 | 2AA | 40 | $4,198 | no | no | <15 min |

## Table 17 Performance Ratings for Telescopic Aids and Night-Vision Equipment

| Ref. No. | Manufacturer | Model | Magnification stabilized | Magnification not stabilized | Field of View | Size | Weight | Durability | Perf Rating | Cost | Perf/Cost Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Telescopic Aids | | | | | | | | | | | |
| 1 | FV | MK111P | 7 | 0 | 6 | 6 | 5 | 5 | 37.6 | 6 | 6.3 |
| 2 | UNITRON | 118C | 0 | 3 | 2 | 9 | 10 | 0 | 36.8 | 2 | 18.4 |
| 3 | UNITRON | 119B | 0 | 1 | 6 | 8 | 9 | 0 | 33.6 | 2 | 16.8 |
| 4 | FV | MK111M | 6 | 0 | 2 | 6 | 5 | 0 | 28.8 | 6 | 4.8 |
| 5 | UNITRON | 111A | 0 | 4 | 4 | 6 | 5 | 0 | 27.2 | 4 | 6.8 |
| 6 | FV | MK X | 9 | 0 | 4 | 2 | 0 | 5 | 24.8 | 8 | 3.1 |
| 7 | ILS | S1040D | 9 | 0 | 4 | 2 | 0 | 5 | 24.8 | 8 | 3.1 |
| 8 | UNITRON | 111B | 0 | 3 | 2 | 7 | 7 | 0 | 28.8 | 4 | 7.2 |
| 9 | UNITRON | 107BS | 0 | 4 | 4 | 5 | 4 | 0 | 24.0 | 3 | 8.0 |
| 10 | UNITRON | 111C | 0 | 1 | 4 | 6 | 5 | 0 | 22.4 | 4 | 5.6 |
| 11 | UNITRON | 125B | 0 | 1 | 2 | 5 | 3 | 0 | 16.0 | 4 | 4.0 |
| Night Vision | | | | | | | | | | | |
| 1 | EEV | P2000 | 0 | 0 | 10 | 8 | 8 | 5 | 37.6 | 7 | 5.4 |
| 2 | NVEC | NVEC 520A GENII | 0 | 1 | 10 | 7 | 6 | 5 | 34.4 | 7 | 4.9 |
| 3 | SDS | VNVA-311 GENII | 0 | 0 | 10 | 7 | 7 | 5 | 34.4 | 7 | 4.9 |
| 4 | NVEC | NVEC 600A GENIII | 0 | 1 | 10 | 7 | 6 | 5 | 34.4 | 8 | 4.3 |
| 5 | SDS | VNVA-311 GENIII | 0 | 0 | 10 | 7 | 7 | 5 | 34.4 | 8 | 4.3 |
| 6 | FV | MK-Vn | 9 | 0 | 5 | 6 | 0 | 5 | 32.0 | 9 | 3.6 |
| 7 | Moonlight | MPN 30K | 0 | 1 | 10 | 3 | 7 | 5 | 29.6 | 5 | 5.9 |
| 8 | Moonlight | MPN 1500 | 0 | 1 | 10 | 3 | 7 | 5 | 29.6 | 8 | 3.7 |
| 9 | SDS | PVS-7B GENII | 0 | 0 | 10 | 4 | 5 | 5 | 26.4 | 7 | 3.8 |
| 10 | NVEC | 1500-4 GENIII | 0 | 0 | 10 | 4 | 5 | 5 | 26.4 | 7 | 3.8 |
| 11 | NVEC | 1500-3 GENII | 0 | 0 | 10 | 4 | 5 | 5 | 26.4 | 8 | 3.3 |
| 12 | SDS | PVS-7B GENIII | 0 | 0 | 10 | 4 | 5 | 5 | 26.4 | 8 | 3.3 |
| 13 | ILS | PVS-5 GENII | 0 | 0 | 10 | 4 | 4 | 5 | 24.8 | 8 | 3.1 |
| 14 | ILS | PVS-7 GENIII | 0 | 4 | 6 | 4 | 2 | 5 | 24.8 | 8 | 3.1 |
| 15 | SDS | GENII | 0 | 0 | 10 | 3 | 4 | 5 | 23.2 | 8 | 2.9 |
| 16 | SDS | GENIII | 0 | 0 | 10 | 2 | 4 | 5 | 21.6 | 8 | 2.7 |
| 17 | ILS | S1040D/N GEN2.5 | 7 | 0 | 4 | 2 | 0 | 5 | 21.6 | 10 | 2.2 |
| 18 | ILS | S1040D/N GEN3 | 7 | 0 | 4 | 2 | 0 | 5 | 21.6 | 11 | 2.0 |
| 19 | Moonlight | MPN 60K | 0 | 4 | 6 | 3 | 0 | 5 | 20.0 | 6 | 3.3 |
| 20 | NVEC | NVEC 800HP | 0 | 0 | 10 | 2 | 3 | 5 | 20.0 | 8 | 2.5 |
| 21 | NVEC | NVEC 800 | 0 | 0 | 10 | 2 | 3 | 5 | 20.0 | 8 | 2.5 |

## 6 Polarized Filter Contrast Enhancement Equipment

Polarized-filter contrast enhancement uses polarized light reflecting from a surface to amplify surface defects. The only company identified which makes field-usable equipment employing this technology is Diffracto, Ltd. Their patented system is named D-Sight™.

The primary purpose of the D-Sight™ system is to amplify surface imperfections in surfaces which appear to be smooth when viewed with standard optical methods. The system consists of a light source and a camera which illuminate and view the inspected surface at an angle. A special reflective screen is placed behind the surface. Some of the light from the source reflects from the inspected surface to the screen and some is scattered directly back to the camera. Some of the light which reaches the screen is then reflected back to the surface and eventually some of that reaches the camera. Interference between the directly scattered and indirectly reflected beams greatly enhances the dark-light contrast in the image of the surface which is caused by defects such as waves, holes, or cracks in the surface. Defects with heights less than 0.001" can be detected.

Both portable and fixed versions of the D-Sight™ system are available. The portable D-Sight™ system consists of a tripod-mounted video camera and light source, a lightweight reflective screen like a portable projection screen, and an electronics package comprising power supplies, an image-processing computer, a viewing monitor, and recording equipment. Depending upon viewing and recording options, the system weighs several hundred pounds.

A reflective or wet surface is required, and physical access to the surface area to be inspected is necessary. Using a portable system, an area about 5 feet square can be inspected in one setup, which takes about 15 minutes. This is essentially a nondestructive testing device, rather than a screening device. It is questionable whether this process has any value as a screening technique for marine inspectors for several reasons: 1) the requirement for physical access to the surface, 2) the need for a clean, reflective surface, the considerable weight and complication of the equipment and the need to continually move it to the surface to be inspected, 3) the fact that many surfaces of interest to inspectors are obstructed by other structure, which would prevent placement of the reflective screen in the proper location.

Inspectors do regularly observe the outside shell of the ship for dents or other evidence of damage which may result in failures of the underlying internal structure. The D-Sight technique might be useful in amplifying imperfections in large unobstructed external areas such as the vessel's sides and deck surfaces. Of these, the deck is certainly the most accessible, and although tankship decks are far from unobstructed, there are large clear areas.

Operation of the D-sight equipment itself requires one trained operator. If large areas were to be inspected in a reasonable time, at least two helpers would be needed to move the screen and camera/projector unit frequently and the electronics console periodically.

A specific training program would have to be developed for this application, after some research to determine how best to use the system in marine inspection environment. Once the application of the system had been defined and perfected, several days of training would be required for principal operators. The principal operators could train their assistants on-the-job.

## 7 Video Equipment

Video equipment has a number of possible applications in marine inspection. Several days of training would be required for principal operators. Remotely operated cameras with magnification and panning capability, monitored by an inspector above decks, could be used for screening large spaces to identify and locate the potential problem areas which require detailed inspection. This could be done without the need for inspectors to actually enter the space, and could allow at least a cursory inspection to be done of a space which is unsafe for human entry. In addition to remote systems, small video camera-recorders (camcorders) might be useful in documenting both overall structural deterioration and specific structural flaws.

A likely application of remote cameras is as an adjunct to a traditional bottom-walking inspection of a tankship cargo space. The video equipment could provide enhanced visibility of the important underdeck structure which is difficult for inspectors confined to the bottom of a tankship cargo space to evaluate.

There are very few off-the-shelf video systems of the deck-based or remote types which would be useful in marine inspection. Most systems of these types are assembled from a combination of standard and custom-made components to suit a particular requirement. The few complete systems which are available have been designed for applications quite different from vessel inspection, such as pipeline inspection.

A typical deck-based system would be based upon a small color video camera, a lens with remotely controlled zoom and focus, lights, possibly with remotely adjustable beam pattern, a pan/tilt mechanism to aim the camera and the lights, and an apparatus for lowering the equipment into a space from above. The camera would be aimed and controlled, and a deck-based monitoring/control station would have capability for viewing, videotape recording, and possibly, color still image printing. The insertion mechanism could be as simple as a cable or as complex as a electrically or hydraulically powered articulating arm.

A typical in-space remote system would use a tripod-mounted camera with remotely controlled pan, tilt and zoom mounted on a tripod. Light would be provided either by spotlights mounted and aimed with the camera or by separate floodlighting that required little or no aiming. Power would be provided from the deck via a cable and control information and data would be transmitted via a cable or a wireless system.

### 7.1 Hand-Held Video Equipment

Portable videotape camera-recorders (camcorders) are the most likely application of hand-held video equipment. Their primary use would be in recording the details of structural problems for documentation purposes and to facilitate repair planning and the Coast Guard's approval of repairs proposed by vessel owners.

Hand-carried video recorders might be useful in documenting damage or deterioration requiring attention during a close-up inspection of problem areas already identified during the screening stage of an inspection. Virtually all video camcorders are equipped with zoom lenses, often up to 10X, and these could serve as telescopic aids to an inspector, although they would not be as efficient as dedicated telescopic equipment. Video camcorders can also be equipped with night-vision equipment, resulting in a monochrome image.

Small video cameras (not camcorders) are described in Section 7.2. While there is no likely application for a hand-held camera without recording capability, such cameras are the primary and most important component of any deck-based or fixed video system. The cameras described in Section 7.2 are miniature color, monochrome, and intensified monochrome cameras.

Specifications and Performance Ratings for Hand-held Video Camcorders

Table 16 presents specifications for hand-held video camcorders and Table 17 gives the performance and performance/cost ratings for this equipment.

## Table 18 Specifications for Hand-Held Video Camcorders

| Ref. No. | Manufacturer | Model | Battery Life (hr) | Size | Weight (lbs) | External Power (vdc) | Cost | Auto zoom | Weather Proof | Shock Proof | Lens (mm) | Magnifi-cation | Stabil-ized? | Video Out | Sensi-tivity (lux) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Panasonic | AG-3 | 1 | 9"x5.5"x4.9" | 2.7 | 120 | $3,300 | yes | no | no | 6-60 | 10/20x | yes | yes | 1 |
| 2 | Sony | FX510 | 1 | 10.5"x4.7"x4.3" | 3.0 | 120 | $1,200 | yes | no | no | 6.1-61 | 10x | no | yes | 1 |
| 3 | Panasonic | AG-455U | 1 | 18.5"x9.5"x5.1" | 7.2 | 120 | $2,300 | Yes | no | no | 5.6-67 | 12x | no | yes | 1 |
| 4 | Panasonic | AG-195U | 1 | 18.1"x9.6"x5.1" | 7.0 | 120 | $1,495 | Yes | no | no | 5-40 | 8x | no | yes | 1 |
| 5 | Sony | TR200 | 1 | 7.7"x4.1"x3.6" | 2.5 | 120 | 1500 | yes | no | no | 5.9-47 | 8x | no | yes | 3 |
| 6 | Panasonic | AG-185U | 1 | 15.2"x8"x3.7" | 5.5 | 120 | $1,035 | yes | no | no | 6.5-52 | 8x | no | yes | 2 |
| 7 | Sony | FX710 | 1 | 10.5"x4.7"x4.3" | 3.0 | 120 | $1,400 | yes | no | no | 6.1-61 | 10x | no | yes | 3 |
| 8 | Hitachi | VM-H39A | 1 | 9.2"x3.9"x3.1" | 2.3 | 120 | $1,600 | no | no | no | 34 | 16x | yes | yes | 2 |
| 9 | Hitachi | VM-2500A | 1 | 14.4"x7.2"x4.2" | 5.0 | 120 | $900 | no | no | no | 37 | 16x | no | yes | 1 |
| 10 | Hitachi | VM-E22A | 1 | 11.3"x4.9"x4.1" | 2.9 | 120 | $900 | no | no | no | 34 | 12x | no | yes | 2 |
| 11 | Hitachi | VM-4400A | 1 | 15.3"x7.7"x5.1" | 5.9 | 120 | $900 | no | no | no | 46 | 16x | no | yes | 2 |
| 12 | Hitachi | VM-5400C | 1 | 15.4"x7.7"x5.3" | 6.0 | 120 | $1,100 | no | no | no | 47 | 24x | no | yes | 2 |

(APPENDIX A)

## Table 19 Performance Ratings for Hand-Held Video Camcorders

| Ref. No. | Manufacturer | Model | Weight | Volume | Zoom Capability | Lowest Light Level | Stabilized Optics | Perf. Rating | Cost | Perf/Cost Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Panasonic | AG–3 | 1 | 2 | 10 | 10 | 10 | 44.0 | 7 | 6.3 |
| 2 | Sony | FX510 | 1 | 2 | 10 | 10 | 0 | 34.0 | 6 | 5.7 |
| 3 | Panasonic | AG–455U | 0 | 0 | 10 | 10 | 0 | 30.0 | 7 | 4.3 |
| 4 | Panasonic | AG–195U | 0 | 0 | 10 | 10 | 0 | 30.0 | 6 | 5.0 |
| 5 | Sony | TR200 | 2 | 4 | 10 | 0 | 0 | 28.0 | 6 | 4.7 |
| 6 | Panasonic | AG–185U | 0 | 0 | 10 | 5 | 0 | 25.0 | 6 | 4.2 |
| 7 | Sony | FX710 | 1 | 2 | 10 | 0 | 0 | 24.0 | 6 | 4.0 |
| 8 | Hitachi | VM–H39A | 2 | 4 | 0 | 5 | 10 | 23.0 | 6 | 3.8 |
| 9 | Hitachi | VM–2500A | 0 | 0 | 0 | 10 | 0 | 10.0 | 5 | 2.0 |
| 10 | Hitachi | VM–E22A | 1 | 2 | 0 | 5 | 0 | 9.0 | 5 | 1.8 |
| 11 | Hitachi | VM–4400A | 0 | 0 | 0 | 5 | 0 | 5.0 | 5 | 1.0 |
| 12 | Hitachi | VM–5400C | 0 | 0 | 0 | 5 | 0 | 5.0 | 6 | 0.8 |

(APPENDIX A)

## 7.2 Deck-Based and Remotely Operated Video Equipment

This category includes two similar groups of equipment. In both groups a video camera with remotely controlled panning and zooming, along with associated lighting equipment, is lowered into a space and is operated and viewed by an observer on deck. In addition to instantaneous imaging, recording capability can easily be added to any remote video system to allow documentation of findings. All remote video systems can be used both as an instantaneous imaging and as a recording system.

The first group comprises systems which use an arm or other extension device, physically anchored to the deck of the vessel and inserted through a deck opening, to support the camera. The second group comprises systems in which a remotely operated and remotely monitored video camera with a tripod or other supporting device is lowered into a space to a flat surface which is part of the vessel's structure.

Deck-based video equipment is likely to be more useful for inspection of tankship cargo spaces than remote cameras on tripods dropped to the bottom of the space for several reasons:

- The underdeck structure is the most difficult part of the structure for inspectors on the tank bottom to inspect, and this would be the most easily accessible area to deck-based cameras.

- A camera at the tank bottom would require long power, control, and data cables or, alternatively, battery power and wireless transmission of control commands and data. For a deck-mounted camera, only relatively short cables are required.

- The upward view of a bottom-mounted camera which was landed on the bottom plating would be obscured by the webs and faceplates of adjacent bottom longitudinals and bottom girders, and to some extent by stringer platforms. In order to be effective, such a camera would have to be landed on the faceplate of a bottom girder. This might be difficult or impossible if the location of deck access points was not convenient.

- A bottom-mounted camera, even if it were on the faceplate of a deep longitudinal or girder, would have a poor view of the structure at the bottom of the space. A deck-based camera would be able to see much of the bottom area, although from a greater distance.

- A bottom-mounted camera would likely require more set-up and handling time than a deck-mounted system.

The four principal components of a remote video system are the camera, the lens with remote controlled zoom and focus and automatic exposure control, a remotely controlled pan and tilt mechanism, and lighting equipment. Monitoring, control, and recording equipment would be located outside the space.

One of the principal potential applications for remote video is inspection of locations too hazardous for human entry. This would require the in-the-space part of the system and the cabling to be approved for Class I, Div. 1 locations. Approved video cameras and remotely controlled zoom lenses are not available. However, cameras and lenses can be used in hazardous locations by enclosing them in approved explosion-proof enclosures, which are available in several sizes, but which greatly increase the bulk and weight of the video system. Approved remotely operated pan/tilt units are available. Several lighting options are also available: metal halogen floodlights in the 400W range, and smaller, lighter, but less intense high pressure sodium floodlights are available in approved versions.

Because of the wiring and cabling necessary between components, a system assembled from approved components might not automatically be permissible for use in hazardous locations. The system, as a whole, might have to be tested and be approved.

The minimum weight for the head unit of a Class I, Division 1 approved remote video system with lights would be about 165 lb, using current off-the-shelf components. The support structure and cables would add considerable additional weight. The cost of the off-the-shelf equipment (approved lights, video camera and lens with enclosure, and approved pan/tilt unit) would be about $13,500. Topside monitoring and recording equipment, power supplies, etc. would add another $3500, dependent upon monitoring and recording equipment. The support structure would have to be developed, and its cost would be dependent upon its complication, upon the number of articulating joints, etc.

A similar video unit which was not approved for hazardous locations could take advantage of miniature camera technology, and would be much lighter. A unit with a miniature color camera with 1 lux sensitivity, 10X remote zoom lens, pan/tilt unit and 500 watt halogen floodlight could weigh as little as 30 lb. The head unit (lights, camera and lens, pan/tilt unit) would cost about $7000. The cost of the topside equipment would be similar to that for an approved system (about $3500), and a support structure would have to be developed and built, but it would be lighter and less expensive than a support structure for an approved system.

An example of a non-approved lightweight video system is a system assembled from the components listed below. The head of such a system could be lowered in completely assembled form through a standard tankship deck opening.

Camera

Cohu 8380 Mini-Remote CCD Color Video Camera with Remote controlled lens. Weighs less than 1 lb, and costs $2510.

Pan/tilt

Remote Ocean Systems Model PT-10 AC powered pan/tilt. Weighs 7.25 lb and costs $3825.

Lighting

Two Collins FX-12 100W spot/55W flood units (12VDC). Weight for two units is 7 lb, and light output is 2,000,000 cp in spotlight mode. Cost with mountings is $500.

Cables

40 ft. of cable to provide the power and control needs of the units listed above would weigh approximately 6 lb. and cost about $150.

Miscellaneous Hardware

Mounting brackets for this system would weigh about 4 lb.

The components listed above make up the head unit of a lightweight video system. the total weight is about 25 lb. and the cost is about $7000. In addition, a support structure would be necessary. A simple rigid tube-type support which would allow the head to be lowered up to 25 ft. into a space through a deck opening would weigh on the order of 50 lb. Since this is a developmental item, cost is not available.

An example of an explosion-proof system is listed below. The head unit of such a system might not fit through a standard deck opening in its operating configuration, but the unit could be designed to be lowered in a folded configuration and opened by remote control once it had been lowered through the opening.

Camera

Cohu 8380 Mini-Remote CCD Color Video Camera with Remote controlled lens. Weighs less than 1 lb, and costs $2510.

Enclosure

Cohu CHX Series Explosion-Proof CCTV Enclosure. Weighs 29 lb. and costs $1560.

Pan/tilt

Bass explosion-proof pan/tilt. Weighs about 65 lb and costs $7500.

Lights

Two Phoenix SXLP 150 Watt approved floodlights. Weigh 22.5 lb. each and cost $800 each.

Cables

40 ft. of cable for power and control would weigh about 15 lb. and cost about $250.

Hardware

Mounting hardware would weigh about 8 lb.

The total weight of this explosion-proof video/light head unit would be about 165 lb, and the cost would be $13,500. A support structure for this system would weigh about 90 lb.

In addition to the head units and support structures, either a lightweight non-approved or an explosion-proof video unit would require monitoring and power supply equipment on deck. this equipment would be similar in nature for either system. Included would be a video monitor, a VCR for recording images, control panel for the camera and pan/tilt unit, and power supplies for the various equipment. The total weight of the above-deck equipment would be in the vicinity of 100 lb.

For the lightweight, non-approved system, an alternate above-deck configuration might utilize a laptop computer with an active-matrix color display as the viewing monitor instead of the customary CRT screen. If the VCR was not required, the total above-deck equipment weight could be held below 40 lb.

### 7.2.1 Availability of Remote and Deck-Based Video Systems

There are no commercially available remote or deck-based video systems which would be usable off-the-shelf for marine inspection. There are several classes of commercially available remote video systems, and while none of them are immediately usable for internal inspections of large vessel spaces, they do demonstrate the possibilities and capabilities of video systems. Virtually all the elements necessary for a marine inspection video system are commercially available; however, no one off-the-shelf device incorporates all of these elements.

At least one custom-made system designed and used specifically for inspection of tankship cargo spaces does exist. Ronald Nisbet Associates, Inc., a nondestructive testing firm, has assembled, from a combination of commercially available video, electronic, and lighting equipment and custom-fabricated mechanical components, a system which they refer to as RemoteView™.

The Nisbet RemoteView™ system is an integrated package consisting of a video camera with remotely controlled zoom mounted with high-intensity floodlighting on a remotely controlled pan and tilt mechanism. The unit can be lowered into a large cargo space on a vessel through standard deck openings and is moved up and down by means of a cable support system. The unit can be remotely controlled and monitored by cables from distances up to 1500 ft. It can display color video images on a display screen and can record moving and still video records of an inspection. Samples of the device's output provided by the owner show high quality, well-illuminated, still color video images. The RemoteView™ system is not approved for use in hazardous locations.

The RemoteView™ unit is certainly too heavy to be carried routinely by inspectors, but it does demonstrate the that remote video inspection is a viable concept. Using the best of presently available technology, a similar device could be designed and constructed which would be much smaller and lighter than the RemoteView™ system.

Remote Ocean Services makes a video surveillance system which could be easily adapted to inspection use. It consists of a remotely operated camera and lighting, connected by cable to a control unit. In its present form, it is designed for inspection at a closer range than would be normal in marine inspection use. It is smaller and lighter than the Nisbet system. Adapting it to inspection use would entail a more powerful zoom lens, which would add virtually no additional weight, and more powerful lighting, which would add some weight and bulk. The cost of this system is $9975.

Cameras

Miniature video cameras are available in several basic types:

- Color CCD cameras, with weights as low as several ounces, and light sensitivity of 1 lux (0.1 footcandles). Costs average $1000 to $2500.

- High-sensitivity monochrome cameras, which have sensitivities down to 0.5 lux without electronic intensification. Costs are in the $750-$1500 range.

- Intensified CCD (ICCD) cameras, which use an image intensifier to produce a monochrome image down to light levels of $10^{-5}$ lux ($10^{-6}$ footcandles). Weights go as low as several ounces. Cost is closely related to sensitivity. A miniature (4 oz) ICCD camera with .01 lux sensitivity costs about $7,000, while those which operate at the lowest light levels cost tens of thousands of dollars.

- Silicon Intensified Target (SIT) cameras, which use image intensifiers similar to those used in night-vision equipment to operate at light levels similar to the intensified CCD cameras, also producing a monochrome image. These cameras are heavier than ICCD cameras and are being replaced by ICCD units.

In addition to these types of cameras, separate intensifier units are available which mount between miniature cameras and their lenses, giving the same levels of sensitivity as ICCD cameras. These intensifiers use Gen2, Gen2.5, and Gen3 intensification technology, and costs are in the $1000 to $3000 range.

Several classes of commercially available video systems were surveyed. Although none of the systems identified were immediately applicable to marine inspection, many used elements of video technology which would have application in a marine inspection video system:

- Borehole and Pipe inspection systems

These systems require miniaturized components, but they are designed to operate at very short, often fixed, ranges, so requirements for lighting and for lens focus and zoom are fairly moderate. Such equipment must be highly resistant to severe environments.

- Underwater video systems

Underwater video systems require cameras and lighting equipment capable of operating at high pressures. Most underwater systems incorporate a limited pan and tilt capability in the lens itself, offering a view of somewhat less than one hemisphere, which decreases the maneuvering requirements for the vessel carrying the systems and may make external pan and tilt mechanisms unnecessary. The magnification available in underwater cameras is often lower than that possible in air, because of the limited range of visibility underwater. In general, video systems designed for underwater use would probably not be the best building blocks for an inspection video system. Underwater video systems are usually based on standard commercially available cameras, fitted with special pressure housings and using specialized lenses.

- Video Surveillance Systems

Fixed video surveillance systems incorporate many of the elements which would be required in a marine inspection video system. High zoom magnification, directable lighting, and remotely controlled pan and tilt mechanisms are all used in surveillance systems, however, weight limitations are not as critical for fixed installations as they would be for portable systems, and the panning and tilting capabilities are generally limited to less than 180°.

### 7.2.2 Possibilities for Development

The area of remote video equipment is one of the most promising for development for several reasons: 1) most of the individual components which would be needed for a remote video inspection system are commercially available and reasonably priced, 2) remote video lends itself well to the screening stages of a marine inspection, and 3) the screening capabilities of a deck-based video system would complement those of inspectors working the bottom of a space. A deck-based system would have access to the underdeck structure, which is the most difficult area for inspectors to screen effectively from the bottom of a large space.

The principal component of a deck-based video system requiring development is the support structure. This could range from a simple rod mounted through a deck opening, on which a video head could be lowered, to a mechanical arm with articulating capability. Using

the lightest possible components for the video/lighting head would, in turn, allow the support structure to be light as possible.

The apparent success of the Nisbet RemoteView™ system indicates a system of this type could be useful to marine inspectors in a number of situations, especially if the weight and bulk could be reduced to a minimum through use of miniaturized and lightweight components.

## 8 Questionnaires

The following questionnaire has been developed to assist with evaluation of equipment in the field. After an initial screening, it is expected that working inspectors will be given one or more items from each group of equipment to be evaluated. The questionnaire will serve as a guide for contractor personnel in quantifying the inspectors' evaluations of the equipment. The principal strategy of questioning is to compare the area and level of structural detail which can be confidently evaluated using the new equipment against what could be confidently evaluated using standard inspectors' tools.



(APPENDIX A)

Questionnaires

The purpose of this study is to identify, and to evaluate in the field, equipment which might help USCG marine inspectors to conduct the initial screening stages of a structural inspection more effectively. We are interested in learning if some of this equipment might allow inspectors to identify problem areas which require more intensive investigation from a greater distance or with greater reliability.

In many of the following questions, you will be asked if a given technique allows you to confidently evaluate the structural condition of various parts of cargo tank internal structure. "Confident evaluation" means that you are satisfied that a detailed, close-up inspection of a given area, which might require staging or other access techniques, is or is not required. (It is assumed that, no matter what the technique, some areas will not be sufficiently visible for the inspector to form a definite opinion one way or the other).

For some categories, such as lighting, there are a large number of devices provided for evaluation. After trying as many of them as possible, please select a few which you feel have the most potential to improve inspection efficiency and evaluate them. In addition to identifying equipment which is usable in its present form, we are also interested in finding out if any of the devices might have potential with simple design changes. Your comments and suggestions for such changes would be appreciated.

Separate questionnaires are provided for Telescopic Aids and Night-Vision Equipment, Hand-Held Lighting Devices, and for Video Camcorders.

Questionnaire for:

Telescopic Aids and Night Vision Equipment

Inspector _____
of MIO/MSO/G-MVI_____

Devices Evaluated:

1. _____ 4. _____
2. _____ 5. _____
3. _____ 6. _____
_____ _____

1. Do you currently use any visual enhancement devices (binoculars, etc) frequently?

Yes _____ No _____

If "Yes", describe the equipment you now use, and when and how you use it:

_____

_____

2. With the level of illumination which was available during this evaluation, at what distance can you confidently evaluate the condition of vessel structure and detect significant structural flaws:

Without any visual enhancement devices? _____ ft

| | | | |
|---|---|---|---|
| With Device #1 | _____ ft | With Device #5 | _____ ft |
| With Device #2 | _____ ft | With Device #6 | _____ ft |
| With Device #3 | _____ ft | With Device #7 | _____ ft |
| With Device #4 | _____ ft | With Device #8 | _____ ft |

3. Describe the level of illumination available when you evaluated these devices.

_____

4. Was the illumination sufficient to allow this device to function to its full capacity?

If not, suggest the type of illumination which would be required to maximize the performance of the devices:

| Device | Yes | No | |
|---|---|---|---|
| 1. _____ | _____ | _____ | _____ |
| 2. _____ | _____ | _____ | _____ |
| 3. _____ | _____ | _____ | _____ |
| 4. _____ | _____ | _____ | _____ |
| 5. _____ | _____ | _____ | _____ |
| 6. _____ | _____ | _____ | _____ |

5. If better illumination could be made available, at what distance could you confidently evaluate the condition of vessel structure?

Without any visual enhancement devices? _____ ft

With the devices evaluated:

| | Device | ft |
|---|---|---|
| 1. | _____ | _____ |
| 2. | _____ | _____ |
| 3. | _____ | _____ |
| 4. | _____ | _____ |
| 5. | _____ | _____ |
| 6. | _____ | _____ |

6. Describe any problems you had in coordinating the aiming of the telescopic devices and the aiming of the lights needed to illuminate the area being observed:

_____
_____
_____

7. During a normal "walking the bottom" inspection inside a tankship cargo space, what percentage of the structure in the following areas can you confidently evaluate, both with this particular device and without it?

Bottom plating and internal structure: Without _____%

| | | | |
|---|---|---|---|
| With | 1. | _____ | _____ % |
| | 2. | _____ | _____ % |
| | 3. | _____ | _____ % |
| | 4. | _____ | _____ % |
| | 5. | _____ | _____ % |
| | 6. | _____ | _____ % |

Side shell and bulkhead plating and internal structure: Without _____ %

| | | | |
|---|---|---|---|
| With | 1. | _____ | _____ % |
| | 2. | _____ | _____ % |
| | 3. | _____ | _____ % |
| | 4. | _____ | _____ % |
| | 5. | _____ | _____ % |
| | 6. | _____ | _____ % |

7. (continued)

Overhead plating and underdeck structure: Without _____ %

With
1. _____ _____ %
2. _____ _____ %
3. _____ _____ %
4. _____ _____ %
5. _____ _____ %
6. _____ _____ %

Comments: _____

_____

_____

_____

_____

_____

8. Does carrying this device impair your mobility?

| | Device | Seriously | Slightly | Not at all |
|---|---|---|---|---|
| 1. | _____ | _____ | _____ | _____ |
| 2. | _____ | _____ | _____ | _____ |
| 3. | _____ | _____ | _____ | _____ |
| 4. | _____ | _____ | _____ | _____ |
| 5. | _____ | _____ | _____ | _____ |
| 6. | _____ | _____ | _____ | _____ |

Comments:

_____

_____

_____

9. Is this device rugged enough to stand up to the handling it would receive in constant use during inspections?

| | Device | Yes | No | Comments: |
|---|---|---|---|---|
| 1. | _____ | _____ | _____ | _____ |
| 2. | _____ | _____ | _____ | _____ |
| 3. | _____ | _____ | _____ | _____ |
| 4. | _____ | _____ | _____ | _____ |
| 5. | _____ | _____ | _____ | _____ |
| 6. | _____ | _____ | _____ | _____ |

10. During what fraction of your inspection time would you carry this device with you?

| | Device | All | None | Some | If "Some", when? |
|---|---|---|---|---|---|
| 1. | _____ | ____ | ____ | ____ | _____ |
| 2. | _____ | ____ | ____ | ____ | _____ |
| 3. | _____ | ____ | ____ | ____ | _____ |
| 4. | _____ | ____ | ____ | ____ | _____ |
| 5. | _____ | ____ | ____ | ____ | _____ |
| 6. | _____ | ____ | ____ | ____ | _____ |

11. Should the Coast Guard make these devices available to all inspection offices?

| | Device | Yes | No | |
|---|---|---|---|---|
| 1. | _____ | ____ | ____ | _____ |
| 2. | _____ | ____ | ____ | _____ |
| 3. | _____ | ____ | ____ | _____ |
| 4. | _____ | ____ | ____ | _____ |
| 5. | _____ | ____ | ____ | _____ |
| 6. | _____ | ____ | ____ | _____ |

12. What improvements or changes to the devices evaluated would make them device more usable, more effective, or easier to carry?

_____
_____
_____
_____
_____
_____

Additional Comments are Welcome:

Thank You



(APPENDIX A)

Questionnaire for:

Hand-held Lighting Equipment

Inspector _____
of MIO/MSO/G-MVI_____

Lights Evaluated:

| | | Battery Type | |
|---|---|---|---|
| | | Disposable | Rechargeable |
| 1. | _____ | _____ | _____ |
| 2. | _____ | _____ | _____ |
| 3. | _____ | _____ | _____ |
| 4. | _____ | _____ | _____ |
| 5. | _____ | _____ | _____ |
| 6. | _____ | _____ | _____ |
| | _____ | _____ | _____ |
| | _____ | _____ | _____ |

1. What type of portable light(s) do you currently carry with you during inspections?

_____
_____
_____

2. Were the lights you evaluated an improvement over your everyday inspection flashlight?

| | Lights | | | Comments |
|---|---|---|---|---|
| 1. | _____ | Yes ____ | No ____ | _____ |
| 2. | _____ | Yes ____ | No ____ | _____ |
| 3. | _____ | Yes ____ | No ____ | _____ |
| 4. | _____ | Yes ____ | No ____ | _____ |
| 5. | _____ | Yes ____ | No ____ | _____ |
| 6. | _____ | Yes ____ | No ____ | _____ |

_____
_____

3. At what distance can you confidently evaluate the condition of vessel structure and detect significant structural flaws

| | | | |
|---|---|---|---|
| With Light #1 | ____ ft | With Light #5 | ____ ft |
| With Light #2 | ____ ft | With Light #6 | ____ ft |
| With Light #3 | ____ ft | With Light #7 | ____ ft |
| With Light #4 | ____ ft | With Light #8 | ____ ft |

4. During a normal "walking the bottom" inspection inside a tankship cargo space, what percentage of the structure in the following areas can you confidently evaluate, both with these lights and with your current light)?

Bottom plating and internal structure: Current _____%

With
1. _____ _____ %
2. _____ _____ %
3. _____ _____ %
4. _____ _____ %
5. _____ _____ %
6. _____ _____ %

Side shell and bulkhead plating and internal structure: Current _____ %

With
1. _____ _____ %
2. _____ _____ %
3. _____ _____ %
4. _____ _____ %
5. _____ _____ %
6. _____ _____ %

Overhead plating and underdeck structure: Current _____ %

With
1. _____ _____ %
2. _____ _____ %
3. _____ _____ %
4. _____ _____ %
5. _____ _____ %
6. _____ _____ %

Comments: _____
_____
_____
_____
_____
_____

5. Could the lights you evaluated be improved by: (note that an improvement in one quality will be accompanied by a degradation in one or both of the others, and an improvement in two qualities will be accompanied by a degradation in the remaining quality)

Higher intensity?
(necessitates higher weight and/or shorter battery life)
Lower weight?
(necessitates lower intensity and/or shorter battery life)
Longer battery life?
(necessitates lower intensity and/or higher weight)

Light # 1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
_____
_____

6. Could the lights you evaluated be improved by any of the following improvements (or others which you may suggest)? (enter letters)

a) A controllable beam pattern?
b) Better carrying provisions
c) More rugged case?
d) Better lens design or material?
e) Better switch design?

Light # 1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
_____
_____

Comments _____

_____

7. If any of the lights you evaluated used rechargeable batteries, did you encounter or would you anticipate any difficulties associated with the use or recharging of those batteries?

_____
_____
_____
_____

8. Should an inspectors' flashlight use:

Disposable batteries? _____
Built-in rechargeable batteries? _____
Disposable or rechargeable at the inspector's choice? _____

9. What do you consider to be the ideal combination of lighting equipment for a single inspector to carry on a cargo tank inspection job? (check all that apply and enter ideal battery life)

Pocket-sized flashlight _____

Battery life _____ hrs.

Standard sized flashlight _____

Battery life _____ hrs.

High-intensity hand lantern _____

Battery life _____ hrs.

Other _____

10. Are these lights rugged enough to stand up to the handling they would receive in constant use during inspections?

| | Light | Yes | No | Comments: |
|---|---|---|---|---|
| 1. | _____ | _____ | _____ | _____ |
| 2. | _____ | _____ | _____ | _____ |
| 3. | _____ | _____ | _____ | _____ |
| 4. | _____ | _____ | _____ | _____ |
| 5. | _____ | _____ | _____ | _____ |
| 6. | _____ | _____ | _____ | _____ |

11. Would you carry these lights with you?

| | Light | Always | Never | Sometimes | If "Sometimes", when? |
|---|---|---|---|---|---|
| 1. | _____ | ____ | ____ | ____ | _____ |
| 2. | _____ | ____ | ____ | ____ | _____ |
| 3. | _____ | ____ | ____ | ____ | _____ |
| 4. | _____ | ____ | ____ | ____ | _____ |
| 5. | _____ | ____ | ____ | ____ | _____ |
| 6. | _____ | ____ | ____ | ____ | _____ |

12. Should the Coast Guard make these lights available to all inspection offices?

| | Light | Yes | No |
|---|---|---|---|
| 1. | _____ | ____ | ____ |
| 2. | _____ | ____ | ____ |
| 3. | _____ | ____ | ____ |
| 4. | _____ | ____ | ____ |
| 5. | _____ | ____ | ____ |
| 6. | _____ | ____ | ____ |

13. What improvements or changes to the lights you evaluated would make them device more usable, more effective, or easier to carry?

_____
_____
_____
_____
_____
_____

Additional Comments are Welcome

Thank You

Questionnaire for:

Hand-Held Video Camcorder

Inspector _____
of MIO/MSO/G-MVI _____

The camcorder is primarily for the purpose of recording the details of problems encountered. The zoom lens might also be useful as a magnification device.

1. Do you ever use a camera or other recording device to record details of your inspections?

   Yes _____ No _____

   If "Yes", please describe what equipment you use, how and where you use it, and how often you use it:

   _____
   _____
   _____

2. Was enough light available to use the Camcorder?

   Yes _____ No _____

   If not, suggest how sufficient light could be made available:

   _____
   _____

3. Was the zoom lens usable as a telescopic device, aside from any video recording functions?

   Yes _____ No _____

4. Is this camcorder rugged enough to use regularly on inspections?

   Yes _____ No _____

5. To what degree does carrying the camcorder impair your mobility?

   Seriously _____ Slightly _____ Not at all _____

   _____
   _____

6. Was the battery life sufficient to allow the necessary information to be recorded?

Yes _____ No _____

_____
_____

7. Did the battery recharging process present any problems?

Yes _____ No _____

_____
_____
_____

8. Would you use a camcorder like this regularly for inspections?

Yes _____ No _____

Why or why not?_____
_____
_____

9. Would any changes or improvements make this camcorder easier to use, easier to carry, or more effective?

_____
_____
_____

Additional Comments are Welcome:

Thank You

# 9 Summary of Recommended Equipment

This section lists and describes equipment which is recommended for purchase or rental and field evaluation. For relatively low-cost items such as hand-held lights, a large number of devices representing a wide range of important characteristics has been chosen. For more expensive equipment, those devices which seem to have the highest potential have been selected. In some categories, several items having similar characteristics have been listed; it is assumed that only one item of a given type will be purchased.

## 9.1 Hand-Held Lights

Since the cost of hand-held lighting equipment is relatively small compared to equipment in other categories, it is recommended that this equipment be chosen primarily on performance rather than on performance/cost ratio. The equipment recommended for purchase represents as wide a range as possible in terms of weight, size, and light intensity. Some of the lights recommended are intrinsically safe, some are not. Since a relatively small percentage of inspections are conducted under conditions which are not safe for hot work, in most cases, non-approved lights can be used. A number of non-approved lights have been included in the recommended list. Some of these offer features or performance which is not available in approved lights.

Approved lights fall into three categories: 1) those carrying Underwriters Laboratories approval for use in Class I, Division 1, Group C & D locations; 2) those carrying Factory Mutual (FM) and/or Canadian Standards Association (CSA) approval as "non-incendive", for use in Class I, Division 2, Group C & D locations; and 3) Mine Safety and Health Administration (MSHA) Approved for Hazardous Locations. Most equipment carrying Class I Division 2 approval is also suitable for use in Class I Division 1 locations. Equipment carrying MSHA approval may be used in shipboard hazardous locations at the discretion of Coast Guard District Commanders. British (BASEEFA) Zone 1 approval is approximately equivalent Class I, Division 1 approval.

Because of the importance of lighting equipment and relatively low cost of portable lights, it is recommended that all or most of the following items be purchased:

Approved Flashlights

Fulton Models N33, N35, and N44 Flashlights (U.L. Approved Class I Div. 1 Gr. C&D)

These are the traditional low-cost standard approved flashlights. These and similar models from other manufacturers are the only flashlights which presently carry UL Class I Division 1 approval. (Many users of approved flashlights have switched to recently available approved lights with more modern and intense bulbs (such as xenon) and lighter weights). Models N35 and N33 use two and three cells, respectively. Model N44 has a right-angle head. The three-cell model, N33 is only approved when using Carbon-Zinc batteries, the other models are approved with either Carbon-Zinc or alkaline batteries. While these lights do not offer exceptional performance, they are the traditional standard inspectors' flashlights, and are included to provide a reference point against which to compare more sophisticated lighting equipment.

Costs: N44 - $6.60
N33 - $9.71
N35 - $5.67

Koehler 8400-T High-Intensity Flashlight (FM and CSA Approved, Class I, Div 2.)

This is a standard-sized flashlight which uses 4 C cells, and produces 25,000 cp from a 5.2V Halogen bulb. It weighs 15 oz. with batteries, and measures 6.3" x 2.5".

Cost: $32.55

Pelican Pro™ #3500 Submersible Flashlight (FM and CSA Approved Non-incendive)

This is a large flashlight with a dual filament xenon bulb which provides instant back-up in the event of a bulb failure (expected bulb life is 30 hrs. per filament). Light output is 40,000 cp, weight is 21 oz. with its 4 C-cell batteries. This light also has two independent switches.

Cost: $52.45

Pelican Super SabreLite™ Submersible #2000C (FM, CSA, MSHA Approved Non-incendive)

This light is a smaller and lighter flashlight than the Pelican Pro, but lacks features like the double filament bulb and backup switch. These lights have been used by CG inspectors. They have a xenon bulb, use 3 C-cells, and weigh 14.5 oz. with batteries. With proper hardhat-mounting equipment this light might be usable as a headlamp.

Cost: $28.60

Pelican MityLite™ Submersible #1900 (FM, and CSA Approved Non-incendive)

This is a pen-light type miniature flashlight, advertised to be the only penlight available which is approved for hazardous locations. It uses two AAA batteries and a 20-hr xenon bulb. It might make a very good backup or escape light.

Cost: $11.80

Koehler Model 100X and 100D Personal Lights (FM Approved Non-incendive)

These are very rugged, very high quality "firefighters' lights", designed to be carried, pocket-mounted or belt-mounted. They produce 30,000 candlepower from a halogen bulb and use a rechargeable battery. They have adjustable focus. Two battery configurations are available, providing 1.75 hrs. (100-D) or 3.5 hrs. (100-X) per charge. The 100-D weighs 18 oz. and the 100-X weighs 30 oz. Various mounting options are available - Clothing and belt clips, velcro straps, and leather wrist straps are available. The 100-D might be adaptable as a head-mounted light. If adapted for disposable batteries, longer life or lower battery weight would be possible.

Cost: $157.00

Streamlight Survivor™ S1-90X (FM Approved Non-incendive)

This light is a "firefighters' light" very similar to the Koehler Model 100. It produces 15,000 cp from a halogen bulb, operates for 1.5 hours per charge, and weighs less than 1 lb. Focus is not adjustable.

Cost: $189.95 list ($144.65)

Note:

Both the Koehler Model 100 and the Streamlight Survivor are possible candidates for further development as a standard inspectors' light. These are both lightweight, very durable high-quality lights. Possible modifications might be adaptation to disposable batteries (which would increase the light output/weight ratio), Class I, Div. 1 approval, or modifications to battery capacity, burn time, or light intensity to suit the inspectors' particular needs.

Approved Hand Lanterns

Bright Star No. 2206 (07050) (UL Approved Class I, Groups C & D)

This is an approved version of the standard floating hand lantern. It produces 2200 cp from a standard bulb and uses one 6 volt disposable lantern battery.

Cost: $11.20

Bright Star No. 2208 (07570) (UL Approved Class I, Groups C & D)

This is a heavier lantern than the Bright Star Model 2206, which uses two 6-volt lantern batteries. The reflector is large and pivots on the battery case. It uses a conventional bulb. This model and the Bright Star Model 2206 are recommended primarily as references, since they represent the older technology in approved hand lanterns.

Cost: $27.19

Koehler Wheat™ Hand-Held Spotlight Model 175 (MSHA Approved)

This is a firefighters' hand lantern which uses rechargeable batteries. Model 175 produces a 15,000 cp beam and operates up to 12 hours per charge. It has an adjustable beam pattern.

Cost: $33.90

McDermott Model EXAFL-1 Portable Handlight (U.L. Approved Class I Div. 1 Gr. C, D)

This is an approved hand-held lantern which uses two 6-volt disposable batteries, and weighs 4.75 lb.

Cost: $130.00 FSN 6230-00-283-9388

King Pelican Lite™ #4000 (FM and CSA Approved Non-Incendive)

This is a small hand lantern which uses a dual-filament xenon bulb with a life of 60 hours and requires eight D-cell batteries. It is water proof to 600 ft. and produces 100,000 cp. Both wide and narrow spot reflectors are provided. The handle can be repositioned for three different grip configurations. Its weight is 2 lb. 10 oz. plus 2 lb. 8 oz. in battery weight for a total of 5 lb. 2 oz.

Cost: $83.85

Pelican DualSix™ hand lantern #4600 (CSA Approved, FM pending)

This light is externally similar to the King Pelican Lite™, but it uses two independent systems, each with four D-cells, a 60,000 cp xenon filament, and separate switches. Each circuit operates for 11-12 hours.

Cost: $60.00

Pelican BriteLite™ #5000 (CSA and MSHA Approved Non-Incendive)

This is a floating pistol-grip hand lantern which uses a xenon bulb with 60 hr life. It projects 60,000 cp and operates 11-12 hours on four D-cells. It weighs 3.75 lb with batteries, and is available with either narrow or wide spot reflectors.

Cost: $40.00

Toplite Hand-Held Searchlight Model 9050 (British Zone 1 and Zone 2 approval)

This light, although heavy (10 lb.), represents the highest light intensity available in self-contained lights approved for hazardous locations. It uses rechargeable NiCad batteries and a 50-watt halogen bulb. Light output is 160,000 cp, with battery life of 1.5 hours on the high setting and 40,000 cp with 4 hour battery life on the "low" setting. The beam pattern is not adjustable; however, given the extremely high intensity, this might not present a serious problem. This light has a toughened glass lens with a safety device which prevents it from being switched on if the lens is broken. A shoulder strap is provided. A special charger is required, and charging time is 16 hours. It meets British standards for safety in all dangerous atmospheres except oxygen-enriched (equivalent to Class I, Div. 1), however, it has not been formally certified by any North American testing organizations (UL, FM, CSA).

Cost: $560.00

Non-approved Flashlights

Mag-Lite™ Flashlights

These are very high-quality consumer flashlights. They are made of aluminum, and are heavy but durable and well-made. Using Krypton bulbs, their light intensity approaches that of more advanced lighting systems. Various models of these lights have been used by many inspectors and, like the standard government flashlights they will provide a baseline performance reference for other lights. Four models are recommended: No. QC-6956 (2 C cells), QC-6957 (3 C cells), QC-4314 (2 D cells), and QC-4315 (3 D cells).

Costs: QC-6956 - $22.80
QC-6957 - $23.70
QC-4314 - $25.50
QC-4315 - $26.40 (Lab Safety Supply Corp.)

Streamlight SL-2DX and SL-3DX

These are similar to the Mag-Lite™ flashlights. The 2DX uses two D-cells and the 3DX uses 3 D-cells. A belt holster is available.

Cost: Both models are $23.00

Non-approved Hand Lanterns

Collins Dynamics CD-12™ Portable Spot/Floodlight

This hand lantern uses a 100 watt H-2 halogen spotlight bulb and a 55 watt halogen floodlight bulb. The integral rechargeable battery gives 60-90 minutes of light output. Weight is 12.5 lb, with the battery package.

Cost: $875

Koehler Wheat™ Hand-Held Spotlight Model 260

These is a non-approved version of the Model 175 firefighter's lantern. In addition to the 15,000 cp beam and 12 hours charge life of the Model 175, Model 260 offers a high range with 45,000 cp, giving a 2.5 hour charge life. It has an adjustable beam pattern.

Cost: $160.00

Maxa-Beam

This light is the most powerful hand-held lantern available. It is not approved for use in hazardous locations. Light output is advertised as 6,000,000 cp with a 75 watt, 12V, xenon bulb. Bulb life is 500 hours. The beam pattern is electrically adjustable from 1 to 40 degrees. The light unit itself weighs 3.2 lbs, and it is connected by a coiled cable to a separate battery pack containing rechargeable NiCad or gel-cell batteries. Battery options range from 5.4 lbs to 11 lbs, and the battery pack can be belt-mounted. A separate battery charger is required, and battery packs can be interchanged. Operating time ranges from one to two hours, depending upon the battery pack selected. This light can also operate directly from a 12 VDC power source.

Cost: $1399.00 (dist. by Xenotech, Inc. and Peak Beam Systems)

McDermott Model A38 High-Intensity Portable Handlight

This is a hand-held lantern, weighing 8 lb., which produces 200,000 cp using a halogen bulb and rechargeable batteries. The charger is built-in and can operate either from 120 VAC or from 12 VDC.

Cost: $190.00

Night Tracker™ RC500K Cordless Spotlight

This is a pistol-grip self-contained hand lantern rated at 500,000 cp. It weighs 4 lb. with rechargeable batteries. Burn time is 1/2 hour. It can be recharged from 120VAC or 12VDC sources and can operate as a 12VDC powered device.

Cost: $58.00

Streamlight LightBox™ Lantern #45131(8WS)

This unit is a firefighter's hand lantern which is standard equipment on many emergency vehicles. It uses a rechargeable battery and has a 25,000 cp halogen bulb. The spotlight head swivels.

Cost: $189.00

Tekna Xena Lite™ #2000

This is a hand-lantern, available with lantern or pistol grips, which produces 40,000 cp. Operating time is 4-6 hrs. on 4 D-cells. It weighs 4.3 lbs. with batteries.

Cost: $33.00

Toplite Hand-Held Searchlight Model 9104 (British Zone 1 and Zone 2 approval)

This is the non-approved version of the Toplite Model 9050 hand lantern. It uses a 100W halogen bulb which produces 200,000 cp. It weighs 8 lb. It uses rechargeable NiCad batteries. Two power ranges are available.

Cost: $560.00

Underwater Kinetics UK 1200

This is a hand-lantern type diving light which uses a xenon bulb and eight D-cell batteries. It has a fixed spot/flood pattern with a wide beam and a bright center.

Cost: $80.00

Non-Self-Contained Hand Lanterns

This category includes 12V hand lanterns designed to be plugged into a separate power supply. While most of these lights are designed for use with vehicle or vessel 12VDC systems, they can also be used as portable hand-held lights when mated with battery packs. They generally use 12V halogen or tungsten sealed beam bulbs and have outputs in the 100,000 - 1,000,000 cp range. Most of these lights have fairly short cords with "cigarette lighter" type plugs. Several belt-mount rechargeable battery packs are commercially available, and are listed below.

Lights having intensities in this range will have short operating times when powered with portable battery power sources, and are thus not suited to continuous use over the course of an inspection unless additional battery packs can be made available during the course of the inspection. The combination of a 300,000 cp light and a battery pack to provide one hour of illumination will weigh approximately 10 lb. Disposable batteries would provide more energy per unit weight and might be more convenient, but at a much higher long-term cost than rechargeable batteries. A fairly light power pack for 12V lights could be based on two 6-volt disposable lantern batteries or eight D-cells connected in series, with a carrying pack and a female cigarette lighter plug; this configuration could be easily prototyped for evaluation purposes at minimal cost.

Since power consumption is such a serious issue with these lights, and since halogen bulbs are much more efficient than other types, lights with halogen bulbs are recommended for over those with tungsten sealed beam bulbs.

Coleman NightSight™ Halogen Spotlight

This is a pistol-grip hand lantern with a plastic body and an 8" dia reflector. It produces 1,000,000 cp from a 12 VDC, 8 amp H-1 halogen bulb with a rated life of 100 hours. the beam pattern can be adjusted from spot to flood by means of a knob. The unit weighs 4 lb.

Cost: $35.00

Collins Dynamics Handheld Spotlights and Floodlights

These are high-quality 12V hand lanterns, designed for law enforcement use. They use standard 12V cigarette lighter plugs. The MAGNUM™ is a spotlight which produces 1,500,000 candlepower from a 100 watt, 7.8 amp H-1 halogen bulb. It uses an 8.5" reflector, and weighs 3.8 lb. The CL-12 and PULSAR™ models are combination spot/flood lights, which produce 1,000,000 cp in spotlight mode. They use 100 watt H-2 halogen spotlight bulbs and 55 watt halogen floodlight bulbs, and draw 7.8 amps on spot and 4.3 amps on flood. The CL-12™ weighs 3 lb. and uses a 7.1" reflector, and the PULSAR™ weighs 2.2 lb., and uses a 7.5" reflector.

The BP-12 battery pack is an option for the lights described above. It is described at the end of this section.

Costs: MAGNUM™ $220
CL-12™ $187
PULSAR™ $100

Dorcy 41-1098 Xenon Spotlight Heavy Duty

This is a consumer-quality hand lantern with a large-diameter reflector, which weighs approximately 2 lb. It can operate on 8 D-cell batteries (an additional 2.5 lb.) or can plug into a 12VDC source. If an external source like a belt-mounted battery pack were used, the internal batteries could be omitted, making the light unit itself very lightweight.

Cost: $10.00

Specialty Lighting Series 2150 Mobile Patrol Light

This is a very high-quality pistol-grip hand lantern. It has a neoprene rubber housing and is advertised as being "virtually indestructible". It has a 12' long coil cord with a plug end. Weight is 2.5 lb. Three bulb options are available: 100 watt - 110,000 candlepower, 50 W - 100,000 cp halogen, and 37.5W - 70,000 cp halogen. Two rechargeable gel cell battery packs are available, with 8 and 4 amp-hour capacities. With the 8 amp-hour pack, burn times are 1, 2, and 2.5 hours, respectively, with the 100W, 50W, and 37.5W bulbs. For battery-powered use, a halogen bulb would be the best choice, since halogen provides the best lighting efficiency.

Costs: 110 - $77.00
100 - $79.00
70 - $78.00

Specialty Lighting Model 2129-1 and 2129-505 Jumbo Jet Utility Light

These lights are very high-quality hand lanterns designed to plug into a 12VDC battery pack. Model 2129-1 has a 100W, 200,000 cp bulb, and model 2129-505 has a more efficient 50W, 160,000 cp halogen bulb. Both models weigh 3 lbs. The housing is aluminum with a neoprene rubber shield, a plastic handle, and a steel wire lens guard. Flood light bulbs are also available. These lights can use any 12V battery pack, including those described above for the Mobile Patrol Light.

Costs: 2129-1 - $123.00
2129-505 - $121.00

Guest Great White™ Hand-Held Lights

These are marine grade hand-held spotlights. The cases are made of rubber, they have 8ft. coiled cords, they float, and they can operate underwater. Three models are available with cigarette lighter plugs: Model 231, 200,000 cp spotlight, Model 233, which has a 200,000 cp spot/flood adjustable beam, and Model 235, 300,000 cp spotlight. The 200,000 cp models draw 7.7 amps at 12VDC. Burn time with, for example, an 11 Ah rechargeable battery pack (which would weigh about 13 lb) would be slightly less than 1.5 hours. Disposable batteries would provide a better battery weight/burn time ratio. Model 234 draws 12.5 amps, and burn time with an 11 Ah pack would be slightly less than one hour.

Costs: 231 - $50.00
233 - $60.00
235 - $58.00

Night-Tracker™ 12VDC Spotlights

These are marine-grade pistol-grip lights. Model RC500K has a 500,000 cp halogen bulb. It has rechargeable batteries and can operate for 1/2 hour on its built-in battery; it can also operate from a 12VDC source using a standard 12V cord. It weighs 4 lb. with battery.

The Nite Tracker 300, Nite Tracker 450, and Nite Tracker XL 1000 are also pistol-grip hand lanterns which are designed to plug in to a 12 VDC source. They weigh 2 lb each. The Nite Tracker 300 uses a 150 watt bulb and produces 300,000 cp. The Nite Tracker 450 uses a tungsten sealed beam bulb and produces 450,000 cp. The Nite Tracker XL uses a quartz-halogen bulb and produces 1,000,000 cp.

Costs:

| | |
|---|---|
| XL1000C | $37 |
| 450 | $30 |
| 300 | $26 |
| RC500 | $58 |

Brinkmann Q-Beam™ Spotlights

These are marine-type spotlights. Several configurations are available:

- The Q-Beam™ Spot/Flood Model 800-1303-0, which combines a 200,000 cp spotlight and a 100,000 cp floodlight in the same unit
- The Q-Beam™ Spot Lite Model 800-1400-7, is a 200,000 cp spotlight.
- The Q-Beam™ Blue Max™ Model 800-1601-0 is a 300,000 cp spotlight.
- The Q-Beam™ Black Max™ Model 800-1951-0 is a 400,000 cp spotlight.
- The Q-Beam™ Max Million™ Model 800-250-0 is a 1,000,000 cp spotlight.

All of the above Q-Beam™ lights use a pistol grip configuration with an ABS plastic case and an 8 ft. coiled cord to plug into a 12VDC source. With the exception of the MAX Million™, they float and can operate underwater. The Max Million weighs 5 lbs, the other models weigh 2.5 lb; all can withstand shocks of 5Gs.

Costs:

| | |
|---|---|
| Max Million | $30 |
| Black Max | $37 |
| Blue Max | $33 |
| SpotLite | $23 |
| Spot/flood | $33 |

Johnson Controls Dynasty™ Battery Packs

These are rechargeable gel-cell battery packs designed for powering portable equipment like lights. They can be belt-mounted or carried with a shoulder strap. The batteries are enclosed in a simulated leather case. A 120VAC charging unit is included, it can be stored inside the battery pack. Both the powered device and the charger connect to the battery pack with a standard cigarette lighter type plug. Three sizes are available: 5 ampere-hours and 7 lb., 9 Ah and 10 lb., and 11 Ah and 13 lb.

Costs:

| | |
|---|---|
| 5Ah | $99 |
| 9Ah | $131 |
| 11Ah | $133 |

Collins Dynamics BP-12 Battery Pack

This is a 12-volt rechargeable battery pack with belt clip, shoulder strap, and recharger. Its capacity is approximately 8 Ah and it will operate the Collins Dynamics CL-12™, PULSAR™, or MAGNUM™ lights (55-100 Watts) for 40-60 minutes. It can also be used for any 12V light using a cigarette lighter plug.

Cost: $200

## 9.2 Head-Mounted Lights

The following head-mounted lights are considered to have potential. As with hand-held lights, it is recommended that all or most of the headlamps listed here be purchased to allow direct comparisons between units in the field.

Approved Headlamps

Koehler Wheat™ Electric Cap Lamp Models 5100 and 5200 (MSHA Approved)

This is the standard high-quality miner's cap lamp for hardhat mounting. It uses a 15,000 cp krypton bulb with two filaments for 550 hours of bulb life. The battery is a 4-volt 15 amp-hour lead-acid rechargeable type giving 12 hours of operation per charge. The battery is housed in a belt pack. Battery weight is 4.7 lb, and the weight of the head unit is approximately 5 oz.

Cost: $271

Mine Safety Appliances (MSA) Ultralight Cap Lamp System #484823 (MSHA Approved for methane only)

This is a high-quality light and is advertised as being the brightest headlamp available. It is explosion proof and uses a tungsten halogen prefocused spotlight bulb. The rechargeable lead-acid battery is contained in a belt pack. The weight of the battery pack is 4.25 lb., and the weight of the head unit is approximately 5 oz. The operating time at full charge is 12 hours. A separate charger is required; battery packs and lamp units are plug-connected. A plug-in emergency escape light, also with a tungsten-halogen bulb, is provided in case of bulb failure.

Cost: $135

Mine Safety Appliances (MSA) MineSpot™ ML-2 Cap Lamp System (MSHA Approved for methane only)

This high-quality light uses a krypton bulb with a secondary safety filament for escape in the event of filament burn-out. It has controllable focus and is explosion proof. The rechargeable lead-acid battery is contained in a belt pack. Total weight is 5.1 lb, 4.25 lb. for the battery pack and approximately 5 oz. for the head unit. The operating time at full charge is 10 hours. A separate charger is required; battery packs and lamp units are plug-connected.

Cost: $123

Note:

MSA headlamps are MSHA approved for methane atmospheres, but are not UL approved for general Class I, Div. 1, Groups C & D because a technicality concerning the bulb ejection mechanism which prevents them from passing the UL test.

Non-approved Headlamps

Birns Diver Lighting System

This is a two-part headlamp which uses a 25 or 50 watt helmet-mount light unit connected by a cable to a rechargeable belt-mount 12V/6 ampere-hour battery pack. It provides 2.5 hours of lighting at 25 watts. The on-off switch is integral with the head-mount unit. The system is designed for diving, and is extremely rugged and obviously waterproof. When used as a diving light, the battery replaces some of the buoyancy-compensating weight normally carried, but without the buoyancy of underwater use it is very heavy (total weight is 7.8 lbs in air).

Bright Star Taurus™ No. 8750

This is an inexpensive self-contained light with a velcro mount for a hardhat. It uses 2 C-cells and a K-2 krypton bulb. The total weight, with batteries, is 11 oz.

Cost: $6

Bright Star No.3550 Headlamp

This is an inexpensive headlamp which uses a separate battery pack. It operates on 3 D-cell batteries and uses a standard PR-3 bulb. The head unit weighs 5 oz. and the battery pack weighs 18 oz.

Cost: $10

Fulton 6200B FulRay™ Hard Hat Light

This is an inexpensive, lightweight self-contained hard hat light which uses 3 AA cells and a standard flashlight bulb (PR-7). It includes a velcro hardhat mount. Total weight with batteries is 11 oz.

Cost: $9

Fulton 14KB-S Headlamp

This is an inexpensive self-contained light which uses 2 C-cells and a krypton K-2 bulb. It is water resistant. It includes a hardhat mounting bracket. Total weight with batteries is 13 oz.

Cost: $12

Garrity Life-Lite™ No. 293

This is an inexpensive, disposable flashlight with a right-angle head, which is used extensively by firefighters, usually in pairs, as a headlamp. No mounting brackets are available, they are generally secured to a helmet or hardhat with tape or with an elasticized web band. Burn time is up to 8 hours in continuous use; shelf life is up to 2 years. If these are to be evaluated, multiple units should be purchased.

Cost: $4

Pelican VersaLite™ #2250

This is a high-quality self-contained pocket/headlamp which uses a 6000 cp xenon bulb. It can be pocket-mounted or hardhat-mounted. It uses 2 AA-cell batteries and weighs 7 oz. with the batteries. Burn time is 6-7 hours. The light head swivels on the battery case/base.

Cost: $19

REI Waterproof Headlamp.

Designed for sport use, this moderately priced self-contained lamp uses a krypton bulb and is waterproof to 30 feet. It uses 4 AA cells and weighs 12 oz. with its batteries.

Cost: $32

Streamlight Top Spot™ II Model #300000

This light converts from a small hand-held flashlight into a wrap-around headlamp which can be used with or without a hardhat. It is self-contained, using 4 AA batteries, which last 4.5 hours. It has a krypton bulb and weighs 8 ounces with batteries. The light head tilts and focus is adjustable.

Cost: $29

## 9.3 Deck-Based Lighting

It is recommended that, at most, one approved 400W floodlight unit, one floor mount non-approved 500W unit, and one non-approved 2000W tripod-mounted floodlight unit be purchased. By unplugging two of the four lights in a 2000W unit, the light output of a 1000W unit can be duplicated.

High-intensity spotlights are very expensive. It is recommended that if spotlights are to be evaluated, they be rented. Rental is easily arranged, since these lights are designed for such uses as outdoor concerts and are regularly rented.

The approved floodlights listed below are the only ones identified in this survey. The non-approved floodlights are representative of similar equipment available from many manufacturers, and their are few significant differences from one manufacturer to another. The spotlights listed are the only ones which will fit through a small opening.

Approved Floodlights

Boss PS400MH Explosion Proof, Weather Proof Manhole Light (Approved Class I, Div. 1)

This is the only high-intensity floodlight identified which is approved for Class I Division 1 Groups C & D locations. It uses a 400 watt halide bulb in a round light fixture, and operates on 120 VAC, with GFCI protection. Weight is 100 lbs for the light and bracket only. The stock version has a 50 ft. power cord and an integral bracket for mounting in a 26" dia. manhole. This bracket is not removable, and would prevent the device from passing through a standard tankship deck opening. The manufacturer has indicated that on special order, but at no increase in cost, the unit could be supplied with a bracket which would allow the unit to pass through an 18" dia. opening. No mounting stand is provided with this light. It can be mounted on a tripod unit, however, its weight is far greater than that of most non-approved floodlight units, and the folding tripod stands used for these units may not be able to handle the approved light.

Cost: $1500

Boss TFEP140MH Tripod Floodlight 400W (Approved Class I, Div. 2)

This fixture uses a 400W metal halide bulb in a rectangular light fixture and includes a folding tripod. Weight is 70 lb.

Cost: $972

Boss S400MH Portable Floodlight 400W (Approved Class I, Div. 2)

This fixture uses a 400W metal halide bulb in a rectangular light fixture and includes a floor stand. Weight is 45 lb.

Cost: $700

Phoenix Model SLXP Explosion-Proof Floodlights (Approved Class 1, Div 1)

This series of lights is available with high-pressure sodium bulbs from 35 to 100 watts and with incandescent bulbs of 110 or 150 watts. Weights range from 22.5 to 25.5 lb.

Cost: $600-800

Non-Approved Floodlights

Boss Model MBS15Q

This is a 500W quartz-bulb floor-stand light which is typical of units from many manufacturers. It weighs 5 lb., is 120VAC powered, and has a metal grating to protect the bulb. The stand supports the light unit about 1 ft. above a surface, and has an integral carrying handle. The weight of the cord required to supply this light in a large space is far greater than the weight of the light unit itself.

Cost: $44

Boss Model MBS15Q-12V

This is similar to the Model MBS15Q described above, but operates at 150W on 12VDC. It is the only DC operated deck-based quartz floodlight identified during this survey. Current draw is 12.5 amps, which would provide slightly less than one hour of lighting with a fairly large (11Ah/13 lb.) portable battery pack. This is the brightest battery powered floodlight identified.

Cost: $95

Wanco Model WT14-4Q

This is a 4-bulb 2000W tripod floodlight. It has four 500W rectangular quartz bulbs. The tripod folds up for carrying and telescopes to a height of 14 ft. It weighs 30 lbs. A similar model, the WTH14-4Q has a stronger, but heavier tripod.

Cost: $435

Boss Model T45QI

This is a 2000W, 4-bulb tripod floodlight which, at 60 lb., is heavier but more rugged than the Wanco unit described above. It uses industrial rated floodlights. A similar unit which uses commercial-rated floodlights is 5 lb. lighter.

Cost: $550

Lab Safety Supply Corp. distributes quartz floodlights similar to those described above. Their line is included in Appendix B (Product Literature) in the section on Deck-Based Lighting.

Non-Approved Spotlights

Spotlights are available in two quite different categories. The first are theater-type spotlights, which generally use xenon bulbs, have power ratings in the thousands of watts, and produce light outputs in the tens and hundreds of millions of candlepower. Even the smallest theater-type spotlights are heavy, and they require heavy power supplies which must be located in close proximity to the light head unit. Most of these lights have optically sophisticated focusing mechanisms and can produce light patterns from an extremely narrow beam to a wide flood light.

The second category is smaller lights of about 100 watts, with candlepower ratings of about 1 million. These are essentially the same light heads used in 12V non-self-contained hand lanterns, with provisions for more permanent mounting. some use more than one bulb to provide both spot and flood service, but as spotlights their beams are not nearly as concentrated as those of the more highly sophisticated theater lights.

No spotlights were identified which were approved for use in hazardous locations, and approval is unlikely, given the high wattages used.

If passage through a small opening like a tankship deck opening is required, the number of available theater-type spotlights is quite limited; 2000W is highest intensity available in a size which can fit through a deck opening. Larger, heavier units with power requirements up to 7000W and intensities in the billion candlepower range are available.

If a spotlight is to be purchased, a 1000W manually controlled unit is recommended. If a rental demonstration of a spotlight is arranged, the 2000W Xenotech unit with full remote control is recommended.

A possible alternative to theater-type spotlights would be arrays of smaller spotlights. The Collins Dynamics FX-12 spot/floodlight head described below is similar to those used in their CL-12™ hand lantern described above. These lights can be mounted on portable tripods.

Phoebus Silverbeam™ PSL-9, 1000W Xenon Searchlight

This high-intensity spotlight will pass through a standard tankship deck opening. It has a 1000 watt xenon bulb, and can operate on 120 VAC. This unit uses a fan-powered cooling system. The head and mounting yoke weigh 52 lb, and a separate ballast is required. The unit can mount on a portable tripod type stand, which is not included. The manual focus control allows the light to function as a spotlight or as a floodlight.

Cost: $8030

Xenotech Britelights™ Model 2000

This is a 2000 watt xenon spotlight which will pass through an opening at least 18" in diameter. It produces 195,000,000 cp. The head itself weighs 40 lbs and two power supplies are available, a 35 lb solid state unit and a 145 lb conventional unit. The spotlight unit can be located up to 100 ft. from the power supply. It has remote controlled on/off/focus and can be equipped with a remote, microprocessor controlled pan and tilt mechanism. A 1000 watt model is available; the case size and weight and the solid state power supply weight is the same as for the 2000 watt unit, but the conventional power supply is lighter (100 lbs.). The 2000 watt costs $11,995 and the 1000 watt unit costs $9995, with solid state power supplies. The 2000W spotlight with wireless remote control costs $34,300.

Rentals are available: The 1000W and 2000W spotlights can be rented for $162.50 and $212.50 per day, respectively. Rental of a 2000W remote-controlled spotlight is $250 per day.

Collins Dynamics FX-12 spot/floodlight head.

This is a 12V AC or DC powered spot/floodlight unit, approximately 7.5" in diameter, and uses weighing 3.5 lb. It has both 100W halogen spotlight and 55W halogen floodlight bulbs. Light output on spot is 1,000,000 candlepower. These light heads are available with bases for mounting on surfaces and clamps for pole-mounting. Any number could be combined into a spot/floodlight array. A heavy-duty 24 volt/70watt bulb system is also available. A 110/12V AC transformer with an output of 40 amps at 12VAC is available

| | | |
|---|---|---|
| Cost: | FX-12 | $210 |
| | Pole mount clamps | $38 |
| | Transformer | $300 |

## 9.4 Telescopic Aids

This listing includes at least one device each of several different types, each chosen to be the best available device of its type. It is recommended that the entire range of equipment listed be purchased (only one stabilized binocular), to allow comparisons between the different types of equipment, i.e., stabilized and unstabilized monoculars, etc.

Unitron Unstabilized 8X Monocular Model 118B

This monocular weighs only 3.9 oz., and represents the lightest and smallest practical magnification device which might be of use to inspectors.

Cost: $78.

Fraser-Volpe Stabilized 10X Monocular Model MK111p

This monocular weighs 21 oz. and provides 10X magnification with a passive stabilization system. It is the lightest possible stabilized magnification device.

Cost: $1200

Unitron Model 133F 7x21 Binocular

This is a compact binocular which weighs 7 oz. It represents the lightest available binocular.

Cost: $144.

Unitron model 107YS 7x50 Binocular

This is a standard high-quality marine binocular. It will provide a baseline reference against which to evaluate other types of magnification equipment, some of which will be monocular, some lighter, some with more magnification, and some which will be heavier but stabilized. This binocular weighs 30 oz.

Cost: $175.

Fraser-Volpe 14X Stabilized Binocular Model MKX

This is a high-powered binocular which has actively (gyroscopically) stabilized optics. It has 40mm objective lenses and is usable in light levels down to about 2 lux (0.2 footcandles). A 10X model is available for the same price.

Cost: $4400

Fujinon Stabiscope™ S-1040D and S-1440D Stabilized Binocular.

These binoculars are very similar, possibly identical, to the Fraser-Volpe stabilized binoculars described above. The 14 power version (S-1440D) is available at the same price as the 10 power version; since both have the same objective diameter, the 14 power version has less light-gathering ability and requires a higher level of illumination.

Cost: $5795 for either version

## 9.5 Night-Vision Equipment

Only magnified night vision equipment is recommended for testing, as it is not expected that 1X night vision equipment will offer any advantage over simple hand-carried lighting. The FV Stabilized night-vision binoculars are the only night-vision equipment which are priced within purchase range. Two of the manufacturers listed below offer rentals of their equipment. If the units are exposed to sunlight or another bright light source even briefly while operating, the phosphor screen will burn out. Each screen costs approximately $2500 to replace. The cost of screen replacement, if necessary, is added to the rental cost. The high-end binoculars have two screens.

Fraser-Volpe MK-Vn 8.4X/15X Stabilized Night-Vision Binoculars

This device is not strictly a binocular; it has two eyepieces but only one objective lens and one intensifier tube (Generation II technology). Similar units (made by Fujinon) with two tubes and two objectives cost about $25,000 (see below). The magnification is 8.4X in night-vision mode and 15X in day mode, and they operate as monoculars with two eyepieces in both modes.

The FV MK/Vn night-vision binoculars can be rented from the manufacturer for $33/day ($1000/month), plus the cost of replacing burned-out screens if necessary.

Cost: $11,625

Fujinon Stabiscope™ Model S-1040D/N Gen 2.5 Stabilized 2.5 Night-Vision binoculars

This unit uses two Generation II Plus intensifier tubes and two 10 power objective lenses. Cost is $25,000. It can be rented from the manufacturer for $86/day or $600/week, plus the cost of screen replacement, if necessary.

Fujinon Stabiscope™ Model S-1040D/N Generation III Stabilized Night-Vision Binoculars

These use two Gen 3 intensifier tubes and two objective lenses. Cost is $45,000. It can be rented from the manufacturer for $100/day or $700/week, plus the cost of screen replacement, if necessary.

Moonlight Products MPN-60K Night Vision Scope

This is Russian-manufactured hand-held monocular scope with 5.2x magnification and Gen 3 intensification (advertised to give 60,000 times light amplification). It uses a single 9-volt battery.

Cost: $1099

Moonlight Products MPN-30K Night Vision Binoculars

This is a true binocular, Russian-made, using a separate Gen 2 intensifier tube for each eye. Magnification is 2.5x, quite low for binoculars. Light amplification is advertised as 30,000 times.

Cost: $999

Moonlight Products MPN-1500 Night Vision Scope

This is a pistol grip scope, Russian-made, with 2.3x magnification, using Gen 1 intensification technology for 1500 times light amplification. It is powered by 6 AA batteries.

Cost: $459

## 9.6 Polarized-filter Contrast-Enhancement Equipment.

The leading example of this technology is the D-Sight™ system of Diffracto, Ltd. Diffracto has quoted a price of $2500 per day plus travel expenses to demonstrate a portable version of the D Sight system at any location specified. Demonstrations at Diffracto's facility in Windsor, Ontario can also be arranged.

## 9.7 Video Camcorders

A number of video camcorders were surveyed which offered features beyond standard consumer quality units. Those which seemed promising are described in Table 18 and rated in Table 19. The Panasonic AG-3 Camcorder is highly recommended.

### Panasonic AG-3 SVHS-C Camcorder

This camcorder is a small unit designed to be hand-held. Its dimensions are 5.5" x 4.75" x 9", and it weighs 2 lbs without batteries and 2.7 lbs with a battery pack that allows one hour of operation. It has 10x optical zoom and 20x digital zoom, electronic image stabilization, and operates in 1 lux (0.1 footcandles) of illumination. It scored well in every rating category and exceeded all other camcorders in both performance and performance/cost ratings.

Cost: $3300

## 9.8 Remote Video Equipment

As noted previously, no existing remote video equipment which is commercially available would meet the needs of marine inspectors. Therefore, none is recommended for purchase. The equipment presented in this section demonstrates the availability of the necessary components of a marine inspection video system, and shows some of the possibilities.

Systems:

Nisbet RemoteView™

This system, described in detail in section 7.2.1, is in fact, a remote video marine inspection system, custom built and the only one of its kind in existence. It incorporates all the essential elements of such a system: a color CCD camera with remote zoom and focus, mounted with lights on a remotely controlled pan/tilt unit, on a frame which can be lowered through a tankship's deck opening, with monitoring and recording equipment located on deck.

Remote Ocean Systems, Nuclear Products Div. Environmental Video Inspection and Surveillance System

This is a remotely controlled video system consisting of a color CCD camera with zoom, focus, and iris controls, and variable intensity lighting mounted on a remotely controlled pan/tilt mechanism. It is controlled by an integrated controller which is connected to the video unit by a cable. The entire video head assembly weighs about 16 lb. The camera has a 6X zoom and operates to 15 lux. The two lights are fixed focus units with three optional beam patterns, with a 75 watt bulb and variable intensity. The entire video head is capable of resisting wet environments. Cost is $9975.

Connecticut Analytical Corporation

Connecticut Analytical proposed an inspection system which would be lowered to the bottom of a tankship cargo space. They quoted a price of $49,000 for a system comprising a color CCD camera with zoom lens and a high intensity light source mounted on a motor-driven turntable with 0°-360° pan and 0°-90° tilt. Control would be from on deck up to 140' from the unit, with a joystick and camera orientation display. A color monitor and VCR would be included in the control station. Cameras proposed are the Toshiba IK-M30A microminiature color camera or the Toshiba IK-C30MAminiature monochrome camera.

High-Sensitivity Monochrome Cameras:

Cohu RS-170 Monochrome 1/2" CCD Video Camera

This is a high-resolution, high-sensitivity monochrome camera. It weighs 15 oz., and takes a standard C-mount lens. It operates in illumination down to .009 lux (.0009 footcandles). Price is $780.

SAIC/SEA Ultravision™ Cameras

This line of cameras weighs less than 1.6 lb. without lenses. They take standard C-mount lenses. The 1" ICCD models are available with Gen2, Gen2.5, and Gen3 intensification, and a 1/2" model without intensification is also available.

Benthos Model 4203 TV ICCD Intensified CCD Monochrome Camera

This underwater camera is 11 in. long and 4 in. in diameter, can be submerged to 1000 meters, and is sensitive to $10^{-5}$ lux. It weighs 7 lb. in air, and costs $21,086.

Miniature Monochrome Cameras:

Micro Video Products Series I and Series V

These are very small, very light video cameras which take C-mount lenses. The Series I is 3.1" x 2" x 1", 2.9 oz., and the Series V is 2.2" x 1.4" x 1.2", 2.5 oz. they operate down to 2 lux. Costs are $210 and $270, respectively.

Benthos Micro TV High Resolution Monochrome Camera

This non-intensified underwater camera operates at light levels down to 0.5 lux. It is 6.1 in. long, 2.5 in. in diameter, weighs 1.6 lb. in air, and can be submerged to 1000 ft. It costs $6121.

Miniature Color CCD Cameras:

Cohu 8280 and 8380 Mini-Remote CCD Color Video Cameras

These cameras weigh 1.75 oz. and operate down to 0.5 lux. They are cable-connected to a control unit by a cable which weighs 7.5 oz/10 ft and can be up to 100 ft. long. Cost of both models is $2510. The camera alone, designated #8210, costs $1450.

Photosea TV3500 High Resolution Color CCD Camera

This is an underwater with a remotely controlled camera and a fixed magnification or zoom lens in a water proof housing 8.5" long, and weighing 2.2 lb in air. the camera operates down to 0.1 lux. Cost is $6750.

Video Camera Accessories:

Intevac CCTV Intensifier Module

These small. light modules provide monochrome night-vision capability for any 1/2" or 2/3" miniature color or monochrome CCD video cameras. They mount in-line between the camera and a standard C-mount lens. An auto-iris lens which limits faceplate illumination to $10^{-3}$ lux is recommended to protect the intensification circuitry. They weigh 13 ounces, and prices start at $2700. The intensifiers use Gen3 technology, and allow the cameras to be usable down to illumination levels of $10^{-5}$ lux.

Cohu CHX Series Explosion-Proof CCTV Camera Enclosure

This enclosure weighs 29 lb., is made of aluminum with a 3/4" plate glass window, and is UL approved for Class I, Div. 1, Groups C & D locations. This enclosure costs $1560.

Remote Ocean Systems Mini Pan and Tilt Model PT-10

This is a small (7.6" x 5.8"), light (7.25 lb.) AC powered pan/tilt unit suitable for miniature video cameras. It is designed for use either underwater or in air. Cost is $3850.

## APPENDIX A Vendor Information

Distributors' names and addresses are indented after manufacturer listings, where no distributors are listed, products can be purchased directly from the manufacturer.

Hand-Held Lights and Lanterns

Boss Specialty Lighting, Inc.
6776 Langley Drive
Baton Rouge, LA 70809
800/933-BOSS

Bright Star Industries
Hanover Industrial Estates
380 Stewart Rd.
Wilkes-Barre, PA 18706
800/631-3814
717/825-1900
717/825-1984 FAX
Dist: Industrial Supplies Corp.
Thomas Rd.
Groton CT 06340
445-9796

Bridgeport Metal Goods Mfg. Co. (Brute™)
365 Cherry St.
Bridgeport, CT 06605
203/366-4701
203/335-9378 FAX

Stewart R. Browne Mfg. Co., Inc.
Box 500008
Atlanta GA 31150
404/993-9600
404/594-7758 FAX

Collins Dynamics/Kwik Raze
div. Havis-Shields Corp.
1725 Stout Drive
Warminster PA 18974-2099
215/957-0720
215/957-0729 FAX

Dorcy International, Inc.
3985 Groves Road
Columbus, OH 43232
614/861-5830
614/863-3054 FAX

Fulton Industries, Inc.
135 East Linfoot St.
P.O. Box 377
Wauseon, OH 43567-0377
419/335-3015
419/335-3215 FAX

Dist: Industrial Safety and Supply
176 Newington Rd.
W. Hartford CT 06110
203/233-9881

Dist: WESCO
178 Wallace St.
New Haven CT 06508
203/777-3601

Garrity Industries
14 New Rd.
Madison CT 06443
203/245-8383

Koehler Mfg. Co.
123-T Felton St.
Marlborough, MA 01752-0918
800/456-2200
508/485-1000
508/485-1004

Dist: C&F Specialty
1181 Old Smithfield Rd.
North Smithfield, RI 02895
800/321-0325
Skip Heroux

Dist: Shipman's Fire Equipment
Waterford CT
442-0678

Dist: Shoreline Fire Equipment
Old Saybrook CT
388-6466

Mag-Lite™
c/o Watts-Spohn Universal
13717 Welch Rd.
Dallas TX 75244
214/385-0192

Dist: Lab Safety Supply
Box 1368
Jamesville WI 53547-1368
800/356-0783

McDermott Light and Signal
1635 Stephen St.
Ridgewood, NY 11385
800/842-5708
718/456-3606
718/381-0229 FAX

Peak Beam Systems (Maxa-Beam Lantern)
402 East Bill Williams Ave.
Williams AZ 86046
602/635-2695
Cheryl

Pelican Products
2255 Jefferson St.
Torrance, CA 90501
310/328-9910
310/523-8160 FAX
Direct
ask for Tiffany

Streamlight, Inc.
1030 W. Germantown Pike
Norristown PA 19403
800/523-7488
215/631-0600
215/631-0712 FAX
Dist: Michael Scranton
15 School House Lane
Middle Haddam CT 06456
203/267-9525

Dist: Lab Safety Supply
Box 1368
Jamesville WI 53547-1368
800/356-0783
(Streamlight Survivor™)

Toplite Technology Ltd.
Tower Bldg., Park Road, Dukinfield
Cheshire, SK16 5LN England
061/330-2867
061/308-4350 FAX

Underwater Kinetics
1020 Linda Vista Drive
San Marcos, CA 92069
619/744-7560
619/744-7320 FAX
Dist: Seaview Scuba Inc.
50 Norwich Rd.
Waterford CT 06385
442-7279

Xenotech, Inc. (Maxa-Beam Lantern)
8211 Lankershim Blvd.
North Hollywood, CA 91605
800/932-XENO

Non-Self-Contained Hand Lanterns and Battery Packs

Coleman

Dist: Northern Hydraulics
P.O. Box 1499
Burnsville MN 55337-0499
800/533-5545

Collins Dynamics/Kwik Raze
div. Havis-Shields Corp.
1725 Stout Drive
Warminster PA 18974-2099
215/957-0720
215/957-0729 FAX

Guest
48-T Elm St.
Station A
Meriden CT 06450
203/238-0550

Dist: M&E Marine Supply Co., Inc.
P.O. Box 601
Camden NJ 08101
609/757-9175

Brinkmann Corp.
4215-T McEwen Road
Dallas TX 75244
214/387-4939

Dist: M&E Marine Supply

Dist: E&B Discount Marine
201 Meadow Road
Edison NJ 08818
800/533-5007
908/819-4600

Nite Tracker
Intermark World Products, Ltd.
632 Green Bay Rd.
Kenilworth IL 60043
312/256-6500

Dist: M&E Marine Supply

Dist: Northern Hydraulics

Dist: Outer Banks Outfitters
Highway 70 East
P.O. Drawer 500
Beaufort NC 28516
800/682-2225

Dist: E&B Discount Marine

Battery Packs:

Johnson Controls

Dist: Advanced Power Technology
2 High Gate Drive
Setauket, NY 11733
516/751-6160
516/751-6164 FAX

Dist: SAGER Electric
60 Reach Road
Hingham MA 02043
617/749-6700
Mr. Joe Wells

Head-Mounted Lights

Birns, Inc.
P.O. Box 909
Oxnard CA 93032
805/487-5393
805/487-0427 FAX

Fulton Industries, Inc.
(see listing under Hand-held Lights)

Garrity Industries
14 New Rd.
Madison CT 06443
203/245-8383

Koehler
(see listing under Hand-held Lights)

McDermott Light and Signal
1635 Stephen St.
Ridgewood, NY 11385
800/842-5708
718/456-3606
718/381-0229 FAX
Direct (EAFXL Lantern FSN 6230-00-283-9388)

Mine Safety Appliances Co.
600 Penn Center Blvd.
Pittsburgh PA 15235
800/MSA-2222
Dist: MSA
1100 Globe Ave.
Mountainside NJ 07092

Pelican Products
(see listing under Hand-held Lights)

REI Inc.
Commercial Sales
1700 45th St. E
Sumner, Wash. 98390-0900
800/828-5533

Deck-Based Lighting and Spotlights

Boss Lighting
Dist: Specialty Lighting Inc.
6776 Langely Drive
Baton Rouge, LA 70809
800/933-BOSS
504/751-2230
504/751-9035 FAX

Dist: Specialty Lighting, Inc.
700-T E. South St.
Anaheim CA 92085
714/778-1840

Collins Dynamics/Kwik Raze
div. Havis-Shields Corp.
1725 Stout Drive
Warminster PA 18974-2099
215/957-0720
215/957-0729 FAX

Lab Safety Supply
Box 1368
Jamesville WI 53547-1368
800/356-0783

Phoebus Manufacturing Div.
Phoebus Corp.
2800 Third Street
San Francisco, CA 94107
415/550-1177
415/550-2655 FAX

Wanco, Inc.
1630 West Evans, Unit L
Englewood, CO 80110
303/935-0617
303/935-1647 FAX

Xenotech, Inc.
8211 Lankershim Blvd.
North Hollywood, CA 91605
800/932-XENO
818/767-0365
818/767-0395 FAX

Telescopic Aids and Night-Vision Equipment

Fraser-Volpe Corporation
1025 Thomas Drive
Warminster Industrial Park
Warminster, PA 18974
215/443-5240
215/443-0966 FAX

Fujinon
Dist: ILS (International Logistics Systems)
234 McLean Blvd (Rt. 20 South)
Patterson, NJ 07504-1295
201/881-0001
201/357-0077 FAX

Moonlight Products
10211 Pacific Mesa Blvd.
San Diego CA 92121
619/625-0300
619/625-0199

Unitron, Inc.
P.O. Box 469
Bohemia, NY 11716
516/589-6666
516/589-6975 FAX

Polarized-Filter Contrast Enhancement

Diffracto Ltd.
2835 Kew Drive
Windsor ON N8T 3B7
519/945-6373 (Windsor)
313/965-0140 (Detroit)
519/945-1467 FAX
Mr. James H. Pogue
Sales Engineer

Portable Video Camcorders

Panasonic Broadcast & Television Systems Company
Div. Matsushita Electric Corp. of America
Government Marketing Dept.
52 West Gude Drive
Rockville MD 20850
301/738-3840

Deck-Based and Remote Video Systems

Nisbet RemoteView™
Ronald Nisbet Associates
P.O. Box 1186
San Pedro CA 90733
310/328-4733
310/320-8551 FAX

P.O. Box 4484
Portland OR 97208
503/283-2668
503/283-7656 FAX
Gary J. Strait
Vice President

Remote Ocean Services
Nuclear Products Div.
5111-L Santa Fe Street
San Diego CA 92109
619/483-3902
619/483-2407 FAX

Connecticut Analytical Corp.
70 Raton Drive
Milford CT 06460
203/876-2720
Joseph Bango

## APPENDIX B EQUIPMENT PURCHASED

This appendix contains the complete list of equipment purchased for use in this study. This list also shows what equipment was evaluated in each test. The initial tests column refers to the initial screening tests discussed in section 3.6. Drawings or photographs of some of the equipment which inspectors generally did not like are included at the end of this appendix.

| ITEM | Initial Tests | James River Tests | Erie, PA Tests | New Orleans Tests | Portland, OR Tests | MIO New York Tests* |
|---|---|---|---|---|---|---|
| Brinkmann Legend Flashlight | X | | | | X | |
| Fulton Model N33 Flashlight | X | | | | | |
| Fulton Model N35 Flashlight | X | | | | | |
| GSA 6-D size | X | X | | | | |
| Koehler Model 8400T | X | X | X | X | X | X |
| Koehler Model 100X | X | X | | | | |
| Koehler Model 100D | X | X | | | | |
| Mag-Lite Model QC-6956 (2C) | | X | | | | X |
| Mag-Lite Model QC-6957 (3C) | | X | | | | X |
| Mag-Lite Model QC-4314 (2D) | | X | | | | X |
| Mag-Lite Model QC-4315 (3D) | | X | | | | X |
| Pelican Pro #3500 | X | X | X | X | X | X |
| Pelican Super SabreLite #2000C | X | X | X | X | X | X |
| Pelican MityLite #1900 | X | X | X | X | | X |
| Streamlight Model SL-2DX | X | X | | | | |
| Streamlight Model SL-3DX | X | X | | | | |
| Stresstel Model T-Mike EZ | | X | | | | |
| Streamlight Survivor Model SL-90X | X | X | X | | | |
| Underwater Kinetics Mini Q40 | | | X | X | X | X |
| Bright Star Model #2206 | X | | | | | X |
| Bright Star Model #2208 | X | | | | | X |
| Collins Dynamics Model 56/2 Genesis Light | X | X | | | | |
| Collins Dynamics Model 56/5 Genesis Light | X | X | | | | X |
| Collins Dynamics Model CD-12 Light | X | X | X | X | | X |
| Eveready Sportgear Light | | | | | | X |
| Eveready Halogen | | | | | | X |
| GSA NICAD Rechargable Dark Blazer 190 | | X | | | | X |
| Ikelite RCD Halogen | | | | | | X |
| Koehler Wheat Model 175 Spot | | X | | | | |
| Koehler Wheat Model 260 Spot | | X | | | | |
| McDermott Model EXAFL-1 | | X | | | | |
| McDermott Model A38 | | X | | | | |
| LSI Night Tracker Model RC-500K | X | X | X | X | X | X |
| Peak Beam Maxa Beam Model MBS-410 Searchlight | X | X | | | X | |
| Pelican King Pelican Pro #4000 | X | | | | | |
| Pelican BriteLite #5000 | X | X | X | X | X | X |
| Pelican DualSix #4600 Lantern | X | X | | | | |
| Streamlight #45131 LiteBox | X | X | | | | |
| Toplite Model 9050 | | | | | | X |
| Toplite Model 9104 | | | | | | |
| Underwater Kinetics Model UK 1200 | X | X | X | X | X | X |

| ITEM | James River Tests Initial Tests | Erie, PA Tests | New Orleans Tests | Portland, OR Tests | MIO New York Tests* |
|---|---|---|---|---|---|
| Bright Star #3550 Headlamp | X | X | | | |
| Bright Star Taurus #8750 | X | X | | | |
| GSA Headlamp | X | X | | | |
| Koehler Wheat Model 5100-G7 Head Lamp | X | | | | |
| Pelican VersaLite No. 2250 | X | X | X | X | X | X |
| REI #K410-150 Headlamp | X | X | X | X | X | X |
| Streamlight Top Spot II Model 300000 | X | | | | X | X |
| Boss Spec. Model S400 Floodlight | X | X | | | | |
| Boss Spec. Model MBS15Q | X | X | | | | |
| Coleman #16380 Spotlight | X | | | | | |
| Collins Dynamics Magnum Light | | X | | | | |
| Dorcy MegaSpot Model 41-1098 | X | X | | | | |
| Guest Great White Model 231 | X | | | | | |
| Guest Great White Model 233 | X | X | | | | |
| Guest Great White Model 235 | | X | | | | |
| LSI 1 Million CP Light | | | X | | X | X |
| LSI Nite Tracker Model SP-300 | X | X | | | | |
| LSI Nite Tracker Model NT-450 | X | X | | | | |
| LSI Nite Tracker Model XL-1000C | X | X | | | | |
| Brinkmann Q-Beam Model 800-1303-0 | X | X | | | | |
| Brinkmann Q-Beam Model 800-1400-7 | X | | | | | |
| Q-Beam Blue Max Model 800-1601-0 | X | X | | | | |
| Q-Beam Black Max Model 800-1951-0 | X | X | | | | |
| Q-Beam MaxMillion Model 800-2500-0 | X | X | X | | X | X |
| Specialty Mobile Patrol Light #2150 | X | X | X | | X | X |
| Specialty #2129-1 | X | X | | | | |
| Specialty #2129-505 | X | X | | | | |
| Steiner 7x50 Rallye Binocular | | X | | | | |
| Steiner 8x30 Rallye Binocular | | X | | | | |
| Unitron Monocular Model 118B (8x25) | | X | X | X | X | X |
| Unitron Binocular Model 133F (7x21) | | X | X | X | | |
| Unitron Binocular Model 107YS (7x50) | | X | | | | X |
| Litton Single Tube | | X | | | | |
| Litton Binoculars | | X | | | | |
| Cygnus Thickness Gauge | | X | | | | |
| Krautkramer-Branson Model DMS Thickness Gauge | | X | | | | |
| Industrial Scientific Model HMX271 Gas Monitor | | X | | X | | X |
| Neutronics Minigas Monitor | | X | | | | |

| ITEM | Initial Tests | James River Tests | Erie, PA Tests | New Orleans Tests | Portland, OR Tests | MIO New York Tests* |
|---|---|---|---|---|---|---|
| ITT Defense Night Mariner Binoculars | X | X | X | X | X | |
| Moonlight Model 1000-I Scope | X | | | | | |
| Moonlight Model 1500-I Scope | X | X | | | | |
| Moonlight Pro Model MPN 30K Binoculars | X | | | | | |
| Moonlight Model MPN 60K Scope | X | X | | | | |
| ITT Defense Night Vision Pocket Scope | | X | X | | | |
| L.L. Bean Fishing Vest | | X | | | X | X |
| Panasonic Model AG-3 Camcorder | | X | | | | |
| Kwik-Vue Model KV-5D6M (lighted mirror) | X | | | X | | X |

* Highlighted items under MIO New York Tests indicate items that MIO New York retained for use. Other items were demonstrated in the office only.

Figure 28 Koehler Model 100X

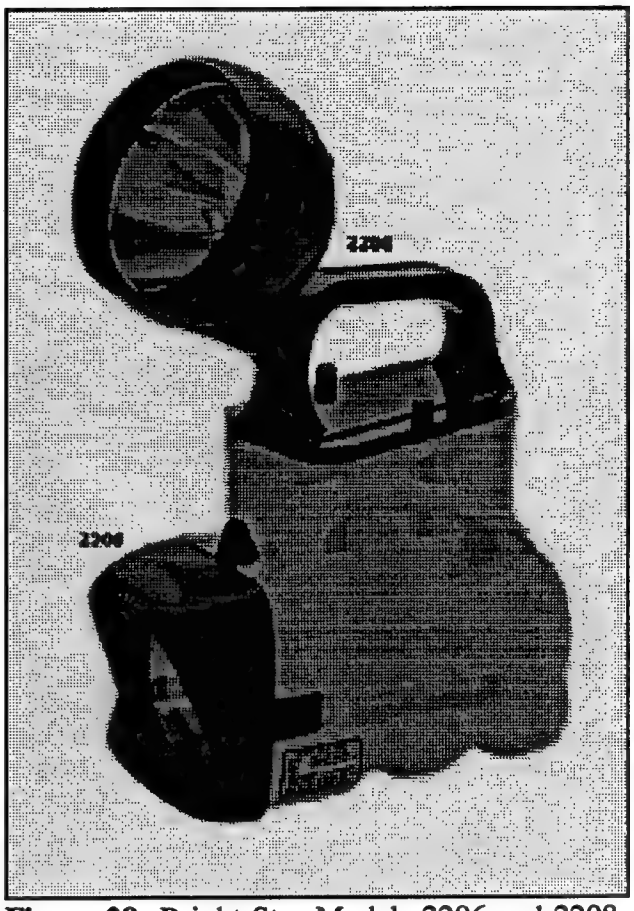


Figure 29 Bright Star Models 2206 and 2208

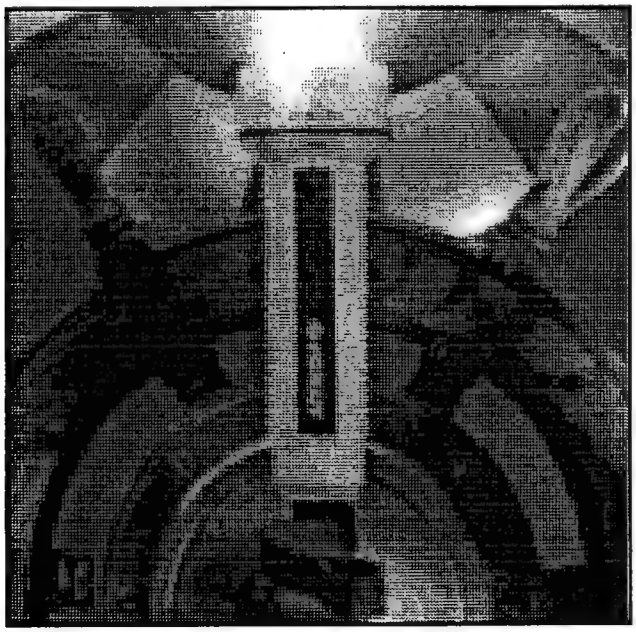


Figure 30 Eveready Sportgear Light

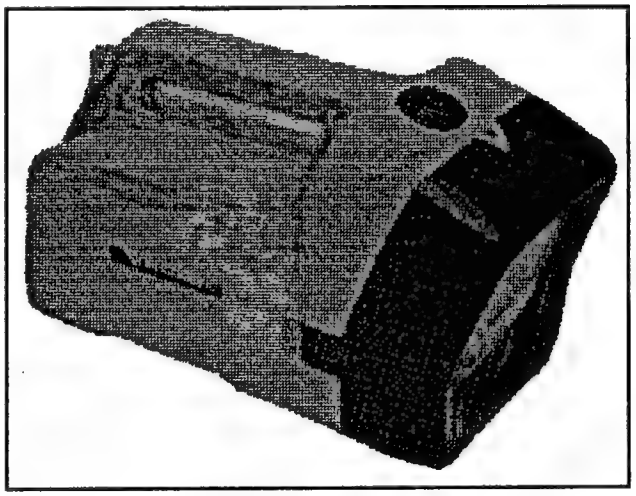


Figure 31 Eveready Halogen Lantern

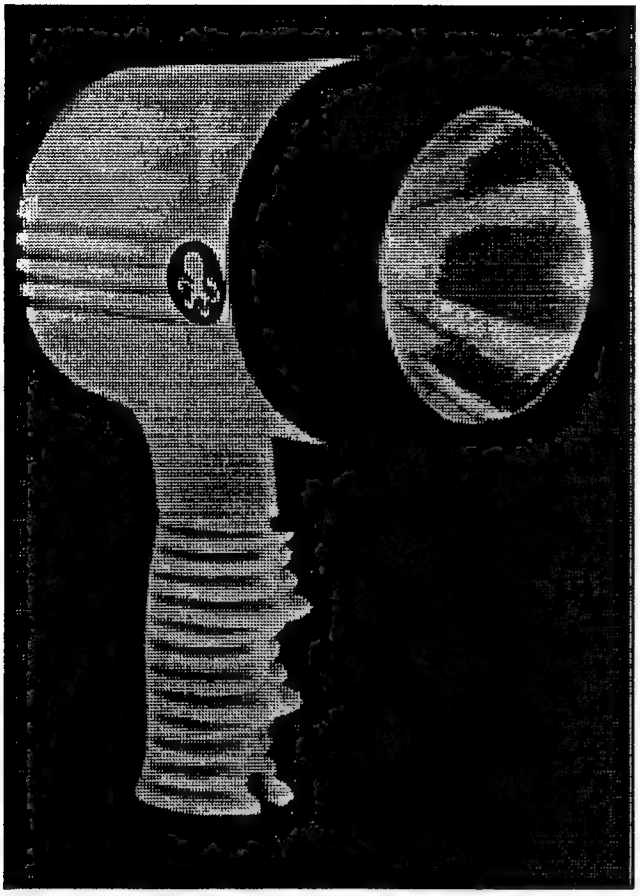


Figure 32 Ikelite RCD Halogen


Figure 33 Koehler Wheat Model 260
(Model 175 is similar)

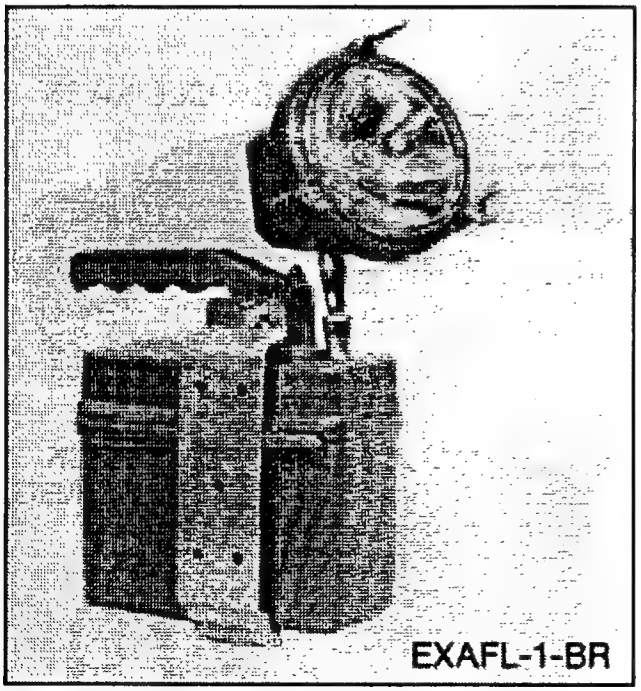



Figure 34 McDermott Model EXAFL-1

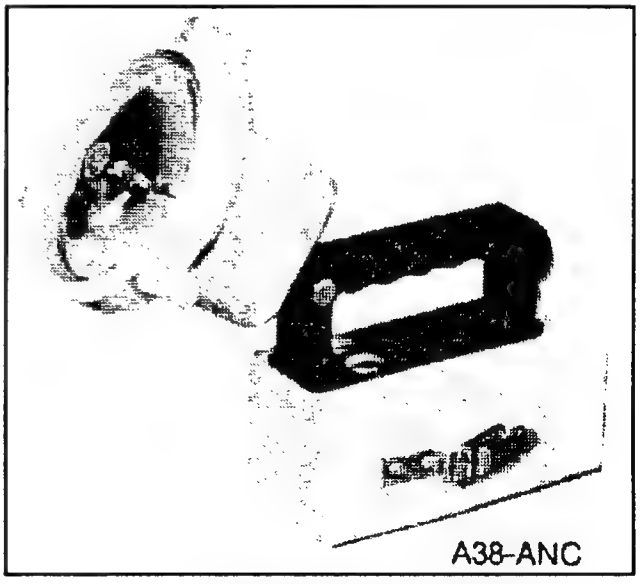



Figure 35 McDermott Model A38

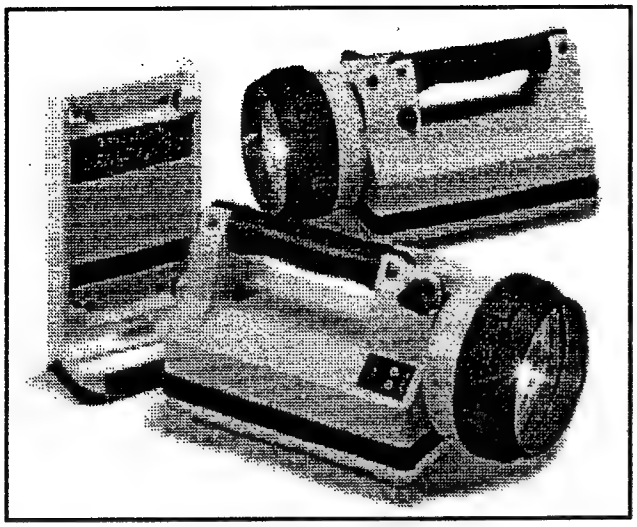


**Figure 36 Streamlight LiteBox**

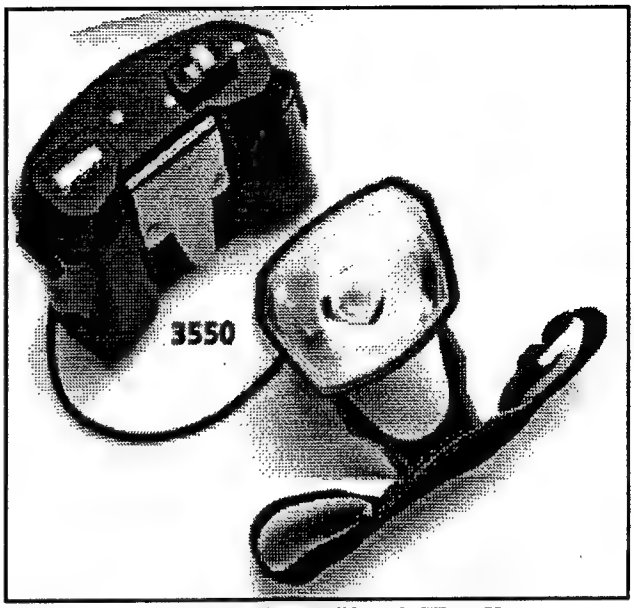



**Figure 37 Bright Star #3550 Headlamp**

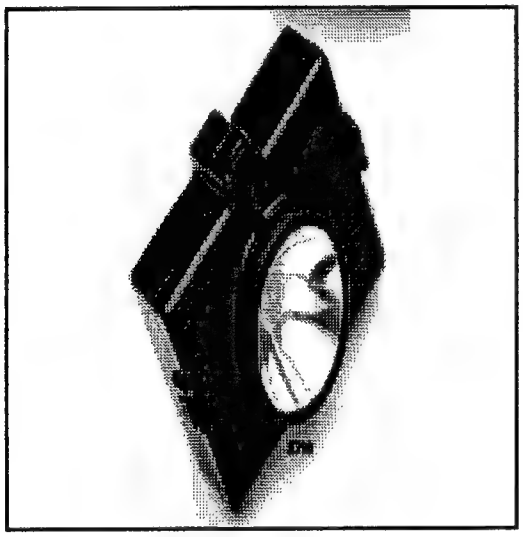


**Figure 38 Bright Star Taurus**

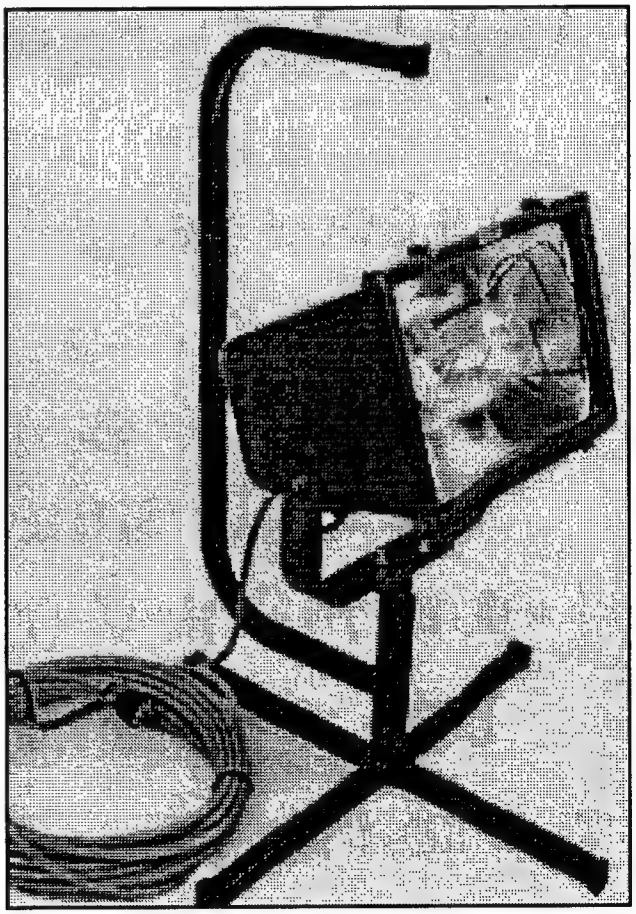


**Figure 39 Boss Specialty S400 Floodlight**

**Figure 40 Boss Specialty Model MBS15Q**


**Figure 41** Collins Dynamics Magnum Light

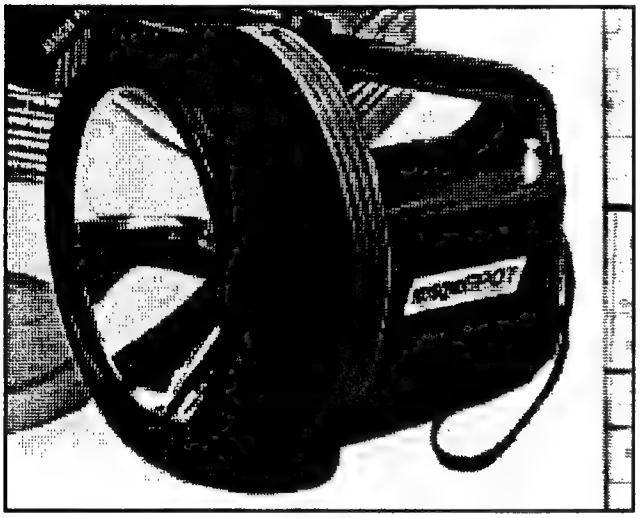


**Figure 42 Dorcy MegaSpot**


**Figure 43 Guest Great White Series**

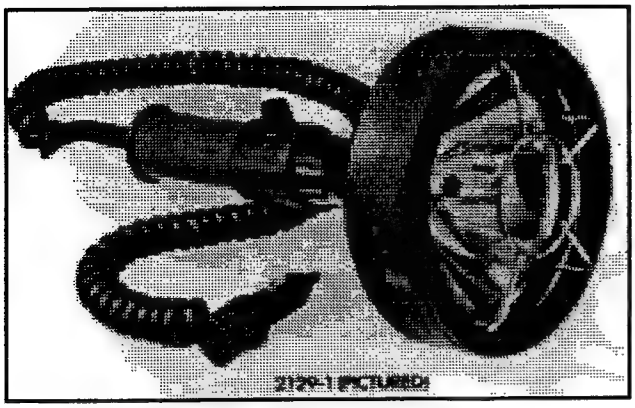


Figure 44 Specialty Model 2129

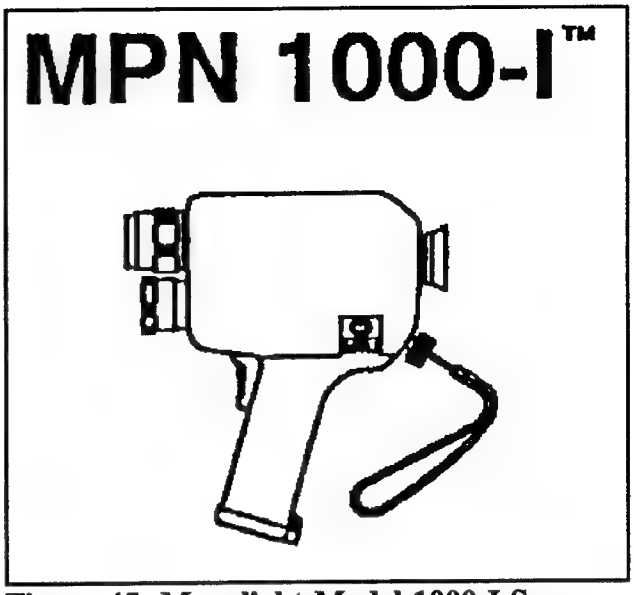



Figure 45 Moonlight Model 1000-I Scope

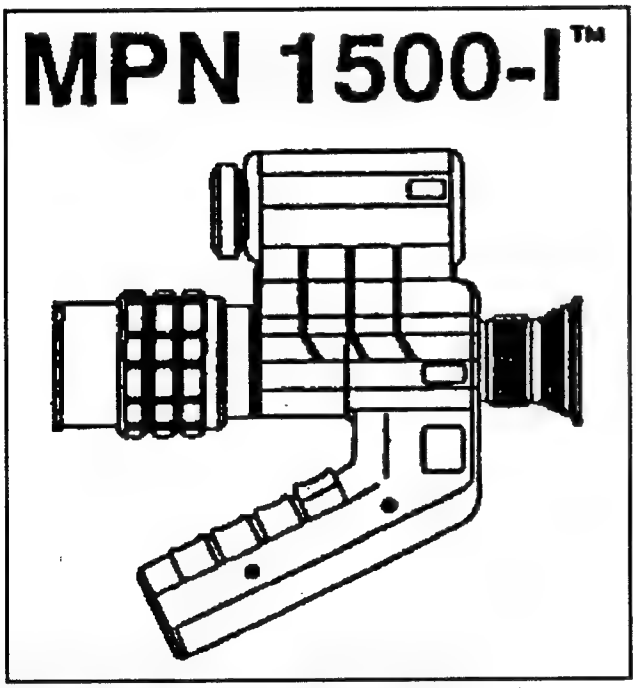



Figure 46 Moonlight Model 1500-I Scope

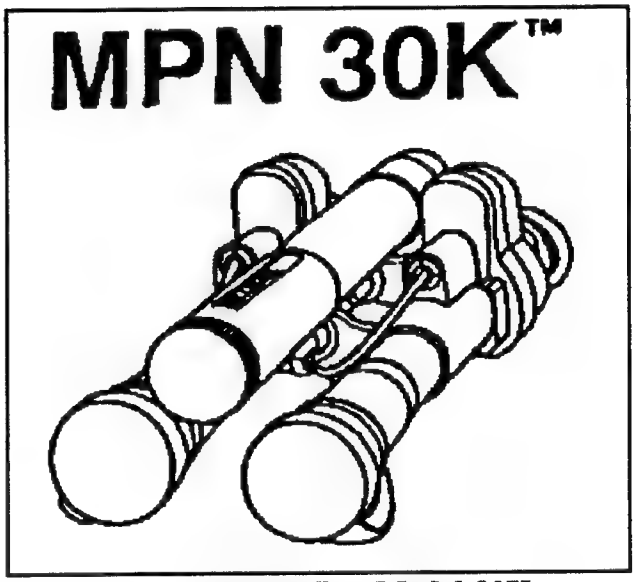



Figure 47 Moonlight Pro Model 30K Binoculars

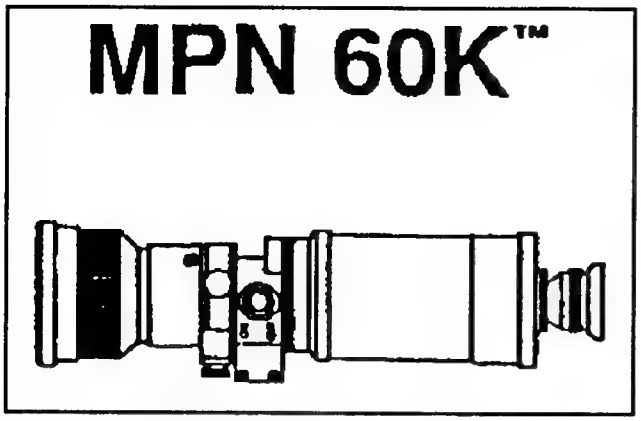



**Figure 48 Moonlight Model 60K Scope**

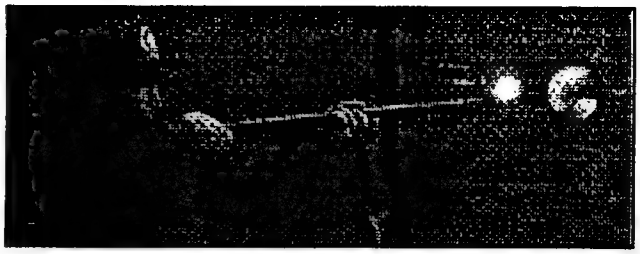


**Figure 49 Kwik-Vue Lighted Mirror**

## APPENDIX C TRIP REPORTS

This section contains trip reports submitted by the contractor, MAR, Inc., after the four field tests at the James River Reserve Fleet, Erie, Pennsylvania, New Orleans, Louisiana, and Portland Oregon, and after the New York office session.

Trip Report
Evaluation of Innovative Inspection techniques
Nov. 15-19 1993, James River Reserve Fleet, Newport News, VA.

**The Inspection Environment**

The tests were conducted aboard the USNS Pawcatuck, a former Navy AO (Fleet Oiler). Two centerline tanks having slightly different entry configurations were used. These tanks, while considerably smaller than those of a VLCC, were similar in construction. The tank interiors were dry and rusty, with no trace of oil, and very little remaining coating. there was no significant structural degradation or wastage anywhere in either tank.

**The Inspectors**

The inspectors who attended the trials were extremely cooperative and helpful. They approached new devices and techniques with an open-minded attitude, and their comments about equipment were not only well considered and candid, but they suggested many small improvements which could make some of the equipment more useful.

The inspectors were, in general, highly experienced. The group included several instructors from the Yorktown training facility, and field inspectors assigned by MSO Hampton Roads as resident inspectors at local shipyards, all billets which require experienced inspectors.

**Evaluation Procedures**

The first day (Monday, Nov. 15) was devoted to moving equipment to the ship, setting up the equipment, and to opening and testing tanks. Equipment was evaluated on Tuesday, Wednesday, and Thursday. Various groups of devices were lowered into a centerline tank, then inspectors were allowed to try out all items from a given group and to conduct comparison trials between the devices. The contractor's representative and/or R&DC personnel were present in the tanks with the inspectors at all times to record the inspectors' comments, to ensure that all devices were evaluated, and to assist with lowering and hoisting of devices.

The inspectors stayed on the bottom of the tanks, occasionally moving around, over and through the bottom structure, and were primarily interested in the performance of the various devices at improving their view of the structure high in the tank where direct access was impossible. Inspectors were given access to the entire inventory of each group of devices. They quickly weeded out those which were clearly inferior to others for one reason or another, then concentrated on comparatively evaluating those which seemed promising. All three groups of inspectors were very thorough and all of the devices seemed to get a very fair evaluation, even those devices which the inspectors clearly didn't expect to be useful before the evaluation began.

The results from each day included a list of devices in order of preference, along with comments on why inspectors liked or did not like certain equipment. Inspectors also offered

comments about desirable features of otherwise unacceptable equipment or undesirable features of otherwise acceptable equipment, which might be useful in specifying improvements or changes.

It is very clear after several days of testing many kinds of equipment that there is no substitute for the real working environment when it comes to evaluating equipment. In many cases, equipment which seemed wonderful on deck had serious drawbacks when used down in the tank, and some equipment which didn't seem too promising on deck proved to be potentially useful when tested in the actual inspection environment. It is very difficult to predict how equipment will perform in a large, dark, non-reflecting space without actually bringing it into such a space. In particular, direct comparisons between two lights often give opposite results on deck and in a tank.

Some of the equipment which was initially purchased, particularly lights, was not brought to the James River test site because earlier comparative evaluations under simulated conditions indicated that it was inferior to other equipment. In light of the experiences of this field test, it might be prudent to reevaluate some of this equipment under actual inspection conditions.

**Flashlights**

Flashlights were defined, for the purposes of these tests, as self-contained lights (with the batteries in the case) which could be carried in a coveralls pocket and which are usually gripped by the body of the light itself.

Most of the inspectors who attended the trials normally use the standard government-issue 3-cell approved flashlights (identical to the Fulton model N33 included in the test group). Some inspectors have replaced the standard bulbs in these lights with krypton bulbs. One inspector uses the Pelican Super SabreLite as his standard flashlight and knows other inspectors who also use this light as their primary flashlight.

The flashlights which inspectors liked the most were the Super SabreLite, the Pelican Pro, and the Streamlight Survivor. Several inspectors said that they would carry one of these lights instead of their standard flashlight, however, others said that none of the flashlights tested were an improvement over their normal flashlight. The Super SabreLite would be more widely accepted if it had a switch which could be operated with one hand, like the Pelican Pro. The double-filament bulb of the Pelican Pro was also mentioned as an advantage - replacing bulbs on-site is often difficult.

Four models of Mag-Lites were tested (2C, 3C, 2D, and 3D), and each was available with standard and krypton bulbs. While the krypton bulbs did not appear much brighter on deck, when compared side-by-side in a cargo tank, it was unanimously concluded that the krypton bulbs provided more intense light than the standard bulbs. Inspectors liked the adjustable beam pattern of the Mag-Lites, but disliked the irregularity of the beam and the dark spot usually present in the center. At least two inspectors would prefer one of the various Mag-Lite models (with krypton bulbs) to the standard flashlight.

The beam pattern of Mag-Lites and other lights using standard flashlight bulbs (krypton or regular) seems to vary considerably with random variations in the heat-sealed top end of the glass bulbs. Other lights which use custom-made bulbs, for example the Pelican lights with their Xenon light units, showed much more consistency in beam pattern; the tops of the bulb units of these lights appeared to be uniformly spherical.

A few inspectors liked the Koehler 8400T flashlight. It is light and bright, but some found it hard to carry because of its unusual shape.

One of the inspectors brought with him a small light which had been part of a firefighting outfit purchased for the Yorktown training facility. It was manufactured by Underwater Kinetics, and is similar to their model Mini Q40. This light was very rugged and well made, and projected a beam as intense as many larger flashlights. It might be useful as an escape light or a backup light.

In general, inspectors favored lights having lanyards or clips over those with no means of attachment. The clips of the Pelican SuperSabre Lite and the lanyard of the Pelican Pro got good reviews.

**Hand Lanterns**

Hand lanterns were defined as self-contained lights (batteries in the light unit itself), too big too put in one's pocket and which generally are carried by a handle. During the evaluations, it became clear that there were in fact two categories of hand lanterns; smaller ones which could actually be carried around by the inspector comfortably for a reasonably long period of time, and larger ones which were best used as fixed lights, positioned to illuminate a large area while an inspector moved around and perhaps used binoculars to inspect the illuminated area. The lights in the first category generally were lighter in weight but with the bulb/reflector unit fixed to the case, so they had to be aimed continuously by hand. Those in the second category were heavier, but generally had a large stable base with a separately aimable bulb/reflector unit. These could be set down on a flat surface like the faceplate of a large longitudinal, a floor, or a web frame, and the light aimed as desired. the inspectors envisioned different roles for the two different categories of lanterns.

Among the portable hand lanterns, the Underwater Kinetics UK1200 was very bright and had a very uniform beam pattern, and the light was a very high-quality and durable unit. However, it was judged as being too heavy for continuous use. This light has an advertised burn time of 7-10 hours. A similar, but somewhat lighter unit, with a shorter burn time would be more useful.

The Pelican BriteLite was acceptable, but not much brighter than a good flashlight. However, with its long burn time, it might make a good light for use with binoculars. the switches of both the Pelican BriteLite and the UK1200 were difficult to use with gloves.

I did not recall seeing the King Pelican Lite at the tests; its specifications indicate that it might be a useful hand lantern; maybe it should be included in subsequent tests. Both the Brite-Lite and the King Pelican are approved for hazardous locations.

The NiteTracker RC500K rechargeable light was almost unanimously rated as the best portable hand lantern. However, this light is not approved, it is not ruggedly constructed, and it has a short burn time (advertised as only 30 minutes). The actual burn times of all lights should be determined before future tests.

**12V Plug-in Lights**

The light intensity available from these lights exceeded that of virtually all other types of lights. There was a great variation in beam pattern and intensity, and intensities were not necessarily correlated with manufacturer's claims of 500,000 candlepower, one million candlepower, etc. In general, those lights with separate bulbs and reflectors were better received than those with sealed-beam units. The sealed-beam lights are heavy, because of the glass sealed-beam units, and they tend to have a dark spot in the center of their beam pattern. Non sealed-beam lights generally had plastic lenses and were much lighter in weight, although many of them did not seem very durable. Inspectors preferred coiled cords to straight wires and they preferred lights with lockable on-off switches or triggers.

The Brinkmann Max Million light was almost unanimously rated as the best of the 12V plug-in lights. Some inspectors liked the Maxa-Beam for its exceptionally white light, but others felt that the dark spot in the middle of its beam pattern and the unnatural color of the light were a disadvantage. The on-off and spot/flood controls of the Maxa-Beam were difficult to operate with gloves, and inspectors repeatedly turned the light off trying to operate the spot/flood zoom control. The Specialty Lighting Corp. "Mobile Patrol Light" was not as bright as the Max Million, and was heavier as well, but many inspectors liked its durability, high quality construction and convenient size. This light's lack of a trigger lock was considered a disadvantage.

More work needs to be done identifying and developing methods for carrying battery packs and plug-in lights. Shoulder straps and belt mounts should be available for battery packs, and several sizes of battery packs should be available. In addition, 12V plug-in lights need some kind of elasticized carrying strap which would allow the inspector to use the lights and to release them without the light units falling.

**Head-mounted Lights**

Head-mounted lights were tried by all of the inspectors present and were universally well-received. Surprisingly, most of the inspectors had never used a helmet-mounted light. Most inspectors present at these tests said that they normally climb ladders with their flashlights in a coveralls pocket, facing up, and lit, which does not provide good local illumination, especially when descending ladders. They often write notes in dark spaces by holding their flashlights in the crooks of their arms to illuminate their notebooks.

Virtually all of the inspectors found them head-mounted lights to be useful. After only one day of trying a headlight, one inspector who had never used a one before said he couldn't imagine ever entering a tank again without one. The Pelican Model 2250 VersaLite, although it was not primarily designed as a head-mounted light, was the most popular, followed by the REI headlight. Both of these are self-contained units, and both can be adjusted easily over a range of vertical angles, a feature which proved to be essential for head-mounted lights in the inspection environment. The REI light is a bit brighter than the Pelican, but it is also heavier and tends to throw the hardhat out of balance and to cause neck fatigue after a day of use. The Pelican is light enough that the wearer really can't tell it is there.

The rubber strap provided with the REI light is excellent, while the elastic band provided for adapting the Pelican for head-mounted use slips off a hard hat, unless it is taped in place. Some inspectors, and myself, used the REI strap on the Pelican light and found this to be a good combination. The Pelican elastic strap taped to a hardhat or the Pelican light attached to a hardhat directly with duct tape also worked perfectly well. I used head-mounted lights for three entire days, the REI for one day and the Pelican for two, and preferred the Pelican. While the Pelican light worked well with the REI strap, the side tabs of the Pelican did not appear strong enough to withstand this configuration indefinitely.

Considering the obvious safety advantages of using a head-mounted light and the fact that their use does not in any way hinder an inspector, I feel that they should be made available to all inspectors and the inspectors should be encouraged to use them. The head-mounted lights provide a constant, low level of illumination for climbing, making it unnecessary to manipulate a flashlight and leaving both the inspector's hands free for safety. When aimed downward, head-mounted lights provide excellent hand-free illumination for such tasks as writing, reading gas monitors, changing flashlight batteries, etc. In addition, a head-mounted light could prove to be a valuable beacon to help others find a disabled inspector in a large space. It was found that an observer at the main deck can very easily keep track of the people in a tank when they are wearing head-mounted lights. The head-mounted lights, especially the Pelican, also serve as an emergency escape light in case an inspector's regular flashlight fails.

Inspectors using headlamps found that they were less likely to keep their regular flashlights burning unnecessarily, for example, when moving around, climbing, resting, or writing, because the headlamp provided a constant, comfortable level of background illumination. It appears that the use of headlamps may extend the battery life of flashlights or allow brighter flashlights with shorter burn times to be used effectively.

Both the REI and Pelican headlamps had satisfactory battery life. Fresh batteries were installed each morning, and many of the headlamps were used almost continuously during the day's tests, a period of about 4 or 5 hours. Both lights maintained full intensity for this time period. Neither the REI or Pelican VersaLite are approved for hazardous locations.

The only headlamp which was approved was the Koehler Model 5200 belt-pack light. However, it required a special miners' hard hat with a mounting bracket, which we did not have,

so it could not be tested. However, inspectors who looked at it felt it was too heavy and the power cable was too much of an inconvenience.

**Binoculars**

Few inspectors had used binoculars, however, many of them found that binoculars had potential uses, especially in inspecting underdeck structure and other structure too high to reach without staging or other access enhancement techniques. The smallest binoculars were found to be the most useful. In particular, the Unitron 7x21 fixed-focus binocular got good reviews. Despite their relatively poor light-gathering ability, the small size and light weight made them a clear favorite. Their fixed-focus optics were also an advantage over other binoculars requiring manual focusing, sometimes separately for each eye. The fixed-focus feature is a particular advantage in dusty and dirty environments in which foreign material could contaminate the focusing mechanism of standard binoculars.

Flashlights were not found to be very effective as lighting devices in conjunction with binoculars. Their beams were either too concentrated and did not illuminate the entire field of view of the binoculars or, if they did have a wide beam pattern, the intensity of the illumination was not sufficient to allow details to be clearly seen through the binoculars. However, in combination with both portable and large hand-held and fixed lanterns and with 12V plug-in lights, many inspectors thought that binoculars had potential.

The greatest difficulty with using binoculars is simultaneous aiming of the light and the binoculars. This can be done with two hands, but this doesn't leave an inspector with one hand free to maintain balance. Two reasonable solutions emerged. The first solution was attaching the binocular to a hand lantern or to the light unit of a 12V plug-in light, allowing one-hand operation. Some inspectors tried this and found it to be effective. The pistol-grip lanterns worked best. Using this technique, the inspector can move about at will and the light is always aimed in the right place; however, the lantern/binocular combination is a bit awkward.

The other solution was to use a large fixed lantern for illumination. The large lantern was set on a surface, its light head aimed, and then the inspector needed only to hold the binocular. The disadvantage of this technique is that the large fixed lanterns are heavy and hard to carry, and they must be moved or re-aimed frequently. However, their intensity is good and their beam patterns are fairly wide by comparison to hand-held lanterns.

Of the non-portable lanterns, the Collins Dynamics CD-12 (not approved) was rated the best by most inspectors, despite its weight and size. Inspectors liked the choice of spot and flood settings, the wide stable base, and the high intensity, which matched that of the best 12V plug-in lanterns. The McDermott A-38 lantern was also found to be acceptable, it was smaller but not as bright as the Collins CD-12.

**Night Vision Equipment**

Night vision devices were not enthusiastically received. In general, they were perceived as fragile, complicated, and expensive, and as offering little in the way of improvement of detailed inspection of vessel structure. Even with substantial illumination, such as from a head-mounted light, the night vision devices did not have sufficient resolution to make structural details at a distance more visible than a good light and the naked eye or binoculars. The unnatural monochrome green image was also perceived as a disadvantage. The American-made night-vision monocular (which had no magnification) was rated as the best device, however, it offered no advantage over a good portable light.

The limited depth of field of all the night-vision devices, especially those incorporating magnification, necessitated constant refocusing. The need to operate two focus controls continuously was seen as a major disadvantage. In general, none of the inspectors indicated that night-vision equipment offered any advantage over good lighting, possibly combined with binoculars.

**Gas Monitors**

Of the two gas monitors tested, the inspectors reacted most favorably to the belt-mounted unit. Many inspectors expressed a desire to carry gas monitors during all tank entries, and almost every inspector has stories of at least one colleague who has been "gassed". However, most inspectors do not now carry them routinely, because suitable units are not available to them.

**Requirements for Approved Equipment**

The inspectors were divided approximately 50-50 on the absolute need for approved equipment. Most inspectors indicated that in practice they rarely enter a space which is not certified as being safe for hot-work. Some inspectors indicated that they would readily use non-approved equipment, especially lights, if they were superior to the approved flashlights they normally carry. Others cited the danger of gas pockets and gases being released from localized crude sludge deposits even in tanks certified as safe for hot-work, and preferred that any light they use in a tank be intrinsically safe. Many inspectors wanted their primary flashlight, the one they carry every day and everywhere, to be intrinsically safe, but indicated that non-approved equipment, such as powerful hand lanterns or 12V plug-in lights might be a useful adjunct where it was safe to use it.

**Recommendations**

Two factors not tested during the initial trials were durability and battery life. A controlled battery life test should be conducted, before the next field trials, for all lighting devices which were found to have potential during this trial, so that battery life information will be available to the inspectors who participate in the next round of tests. In addition, all lights and other devices which have survived the initial cut should be drop-tested. Any device which cannot survive a drop

from normal carrying height (3 to 5 feet) to a hard surface without serious impairment of its function may not be suitable for use in tank inspections.

Future field evaluations will obviously be conducted with a much smaller number of devices, many having been eliminated from contention by these tests. because of the large number of devices in these tests and the desire to have every inspector try all of them, many devices, even those which were rated highly by the inspectors, were actually used for only a few minutes, and inspectors rarely moved about very much with any one item. During future tests, inspectors should be encouraged to use the most popular devices for as long a time as possible and to move around and climb a lot while using them, so that battery life limitations and ease of carrying can be more closely scrutinized.

If possible, greater numbers of the more popular items should be provided for the next round of tests. In some cases, these have been purchased but were not brought to Newport News, in other cases, additional purchases may be necessary.

Pelican VersaLite - bring all 6 which have been purchased. Consider purchasing more so they can given to the inspectors participating in the tests.

REI headlamp - bring all 6 which have been purchased.

Pelican Pro flashlight - three were initially purchased, one was lost, bring the other two and consider purchasing three more.

Underwater Kinetics Mini O40 light - One which was brought by inspectors was used and was rated favorably - consider buying a few for future tests.

Streamlight Survivor - bring all three with chargers.

Koehler 8400T Flashlight - bring all three.

Brinkmann Q-Beam Max Million Spotlight - Bring all three.

Battery Packs - A wide assortment of battery packs should be brought to future tests, including belt adapters for the Johnson Controls battery packs.

Nite-Tracker RC500K Cordless Spotlight - This light was the best-liked self-contained hand lantern. Three were purchased, bring them all to future tests.

Pelican BriteLite, King Pelican Lite - both of these are available with "LaserSpot" and "Modified Spot" reflectors. Both models of each should be included in future tests.

Additional binoculars - The Unitron 133F (7x21) compact binoculars were very well received, much more so than any of the full-sized units. Unitron also makes 8x21, 8x25, 9x25, and 12x25 compact units in the same size and weight range as the 133F. Now that

binoculars have been shown to have potential, and compact binoculars appear to be heavily favored over full-sized ones, it might be useful to compare and evaluate a number of different compact models.

Additional Flashlights - The local "Boater's World" store sells a high-quality 2D-cell, krypton bulb flashlight by Tekna which appears to be essentially a plastic copy of the aluminum Maglite, and which is considerably lighter than the equivalent Maglite. Many inspectors liked the Maglites, but thought that they were a bit heavy. This Tekna light might be a good item to test on further field trials.

The same vendor also sells a small approved light by Pelican which is a bit different from the Super SabreLite which we tested.

West Marine, a west-coast based marine mail order firm, lists two new halogen-bulb lights by Eveready in their latest catalog. One of these is a flashlight, one a hand lantern. Since halogen bulbs are just beginning to appear in hand-held lights and they appear to offer advantages over other types, these lights might be interesting to test.

Trip Report

Evaluation of Innovative Inspection Techniques

**Trip to Erie PA March 7-9, 1994**

On March 7-9 1994 I accompanied Mr. Kurt Hansen of the R&D Center to Erie Pa. in support of the "Evaluation of Innovative Inspection Techniques" project. The purpose of this trip was to accompany Coast Guard Inspectors on an inspection of a bulk carrier and to assist them in evaluating equipment which might improve their inspection techniques. The equipment to be evaluated included portable lights, night-vision equipment, gas monitors, binoculars, and various systems for carrying equipment.

Two vessels were visited: the Kaye E. Barker, a small (750') older steam-powered bulk carrier which had been lengthened and converted to a single-conveyor self-unloader, and the James. R. Barker, a more modern and larger (1000') triple-conveyor self-unloading bulk carrier. Both vessels were at the Erie Marine Enterprises shipyard, having undergone repairs over the winter. Both vessels had most recently carried taconite pellets (iron ore), but they also carry coal and other bulk cargoes on occasion.

The two inspectors had come from MSO Buffalo, NY specifically for the purpose of evaluating equipment; this was not a regular inspection. All of the cargo spaces on both vessels were closed. During a regular inspection, the cargo space hatches would be opened for an internal examination of these spaces, except when the inspectors were evaluating the watertightness of the hatches.

Both bulk carriers are transversely framed, with double bottoms, and with ballast tanks outboard of the lower parts of the cargo spaces. The only primary structure located in the cargo spaces is the transverse deck framing. Secondary structure in the cargo spaces includes the transverse bulkheads and their associated framing.

Areas entered with the inspectors included a ballast tank, a boiler, the unloading tunnel (which was lighted) on the smaller vessel and cargo spaces on both vessels. There were recently completed structural repairs in the ballast tank and the cargo space of the smaller vessel, and several unrepaired weld failures were discovered while in the cargo space of the larger vessel.

**The Environment**

There are four principal environments for internal structural examinations on bulk carriers:

<u>The Upper Levels of Ballast Tanks</u>

Here there is adequate headroom. The sideshell transverse framing is visible, and with the installed catwalks and platforms, an inspector can get to within about 15' of any area to be inspected.

The Lower Levels of Ballast Tanks

These spaces are wet and muddy, overhead as well as underfoot, and access is by crawling through the lightening holes in the bottom transverse and longitudinal framing members. There is kneeling headroom at best. All inspection is done at close quarters, so lights need not project a great distance. Since ballast tanks are relatively small, the inspector is never far from access to the upper level. Air quality in all parts of ballast tanks is generally good, since the constant filling and emptying in service brings in many changes of air. Toxic gas (hydrogen sulfide) is not a problem in ballast tanks on Lake vessels.

Double-bottom Spaces

These spaces are similar to the lower levels of ballast tanks, with the transverse and longitudinal framing forming small cells and lightening holes providing the access. Although not as wet and muddy, headroom is often even less than in lower levels of ballast tanks, and the double-bottoms extend continuously for the length of the cargo area on each side of the keel girder, so an inspector must spend several hours in the cramped conditions working his or her way through. Ventilation and air quality may be poor, as there are few changes of air in these spaces. Inspectors prefer to carry as little equipment with them as possible in these spaces, as anything hanging from the waist or even in pockets interferes with crawling through the lightening holes. Both inspectors and yard personnel used homemade rope harnesses on their flashlights which allow them to carry the lights hands-free at the side of their chests, facilitating movement through tight spaces.

Cargo Spaces

These spaces are large (up to 150' long, 70 ft. wide, and 60 ft. high), and are dry and dusty. Inspectors move around the bottom by unassisted climbing on the slope sheets and the "hogback" separators between the cargo bays. Climbing chains are provided only where it is necessary to climb the slope sheet to get to access ladders. There are no horizontal surfaces anywhere in the cargo spaces except the small hatch opening at the bottom of each bay which leads to the unloading conveyors. Physical access to upper levels, where most of the important structure is located, is virtually impossible without staging. All inspections of internal structure are done with the hatches opened in daylight. With the hatches closed, inspectors evaluate hatch integrity and sideshell pitting by looking for light leaks.

I was carrying a backpack with about 20-25 lbs of equipment in both cargo spaces, and found this to decrease my mobility significantly in this situation.

By comparison to tankship inspection, bulk-carrier inspections involve less climbing but more crawling in tight spaces. While most of the important structural members of tank vessels are located in the large cargo spaces, the structure of bulk carriers is largely visible only in the confined spaces of the ballast tanks and double bottoms. Therefore, in a bulk

carrier, there is less distant viewing of structural components, especially in dark spaces, so there is less need to project high light intensity over long distances.

**The Inspectors' Normal Equipment**

One inspector carried a "Mag-Lite" (3 D-cells) as his standard light and one "Mini Mag-Lite" (2 AA cells) as an escape light. The other carried a GSA 6 D-cell plastic hand lantern, with a Mini Mag-Lite for an escape light. Neither had used head-mounted lights, large hand lanterns, or binoculars for inspections.

Both inspectors pointed out that there is no "standard" set of equipment which inspectors carry; their equipment varies with the type of vessel and the space being inspected. The type of lighting equipment required also varies with the particular inspection.

**Thickness-Gaging Equipment**

Neither inspector saw any need for inspectors to carry ultrasonic thickness-gaging equipment; they preferred to have NDT technicians engaged by the vessel owner perform this work. One inspector felt that if CG inspectors carried and used this equipment, vessel owners might come to rely upon them for thickness-gaging. They pointed out that in many cases, the surface cleaning which the yard does in preparation for thickness-gaging by an NDT technician results in penetration of the plating or other indications that renewal is clearly necessary. The plating is then renewed without any need for gaging.

**The Need for Approved Equipment**

There are only a few situations in which equipment used on bulk carriers needs to be approved for use in hazardous locations. Coal dust is the only explosive atmosphere which ever exists on bulk carriers, and coal is generally a secondary cargo. Cargo spaces and the unloading tunnels of self-unloaders could have explosive atmospheres when handling coal, but the ballast tanks and double-bottoms, where most of the structural inspection is done, do not present explosion hazards. It is unlikely that an inspector would encounter an explosive atmosphere during the course of normal inspections; this would be more likely to happen during casualty investigations involving vessels carrying coal.

**Gas Monitors**

For inspectors in the Lakes, explosive atmospheres and toxic gases are not generally a concern. Oxygen deficiency is the only common hazard. The inspectors interviewed said that their office uses the Neo-Tox oxygen meters, but that they are not satisfied with these. They would like a small, light, reliable meter for oxygen, and did not need explosive and toxic indication. Because of the tight-space problems crawling double-bottoms, belt-mounted units are difficult to use; a pocket-type meter is better. Inspectors in the Lakes region often work in very low temperatures, gas monitors for use there should be usable to at least -10F. The units we brought are usable down to about 0F.

**Flashlights - General Observations**

Many of the newest generations of flashlights are diving lights or are patterned after diving lights. For watertight integrity many of these lights have only one opening - the connection of the lens to the body - and this is sealed by an O-ring. A number of lights use the lens-turn switching arrangement, in which twisting the lens moves the bulb into and out of contact with the batteries, eliminating the need for a separate switch. Several of these types of lights are approved for hazardous locations, and, with xenon or halogen bulbs and plastic cases, they offer high brightness for their weight. While these lights have advantages in terms of maintaining watertight integrity, they pose several disadvantages in the inspection environment:

- Lights using lens-turn switching require two hands to turn on and off - definitely a disadvantage to many inspectors.

- The beam pattern is generally fixed - many inspectors prefer lights such as the Mag-Lite in which the beam pattern can be adjusted.

- In order to replace the batteries the entire light must be disassembled, exposing the bulb, reflector, switch contacts, and sealing O-ring to any dirt or dust which may be present in the environment. The parts are also difficult to control once the light is disassembled and they can be easily dropped or lost while changing the batteries. Lights with lens-turn switching have a spring which holds the reflector against the lens and which tends to make the parts fly apart when the light is disassembled. In some lights the spring is another loose part to be dealt with when the light is apart. In some cases, the bulb/reflector unit must be carefully installed into the body of the light with an aligned keyway. Replacing batteries in these lights could be difficult in the dark.

- The lens-turn switching mechanisms are prone to jamming in the "on" position, especially after becoming contaminated by dust. A jammed light must be disassembled to correct the problem, which could necessitate disassembly in a difficult location even if the battery life was sufficient to make battery changes unnecessary while inside the space being inspected.

- It is possible to inadvertently unscrew the lens too far when turning the light off, resulting in an unwanted disassembly. This is particularly true with the Pelican Versa-Lite when it is mounted on a hardhat.

- Virtually all lightweight lights have plastic lenses, which are prone to degradation by scratching in the dusty environments found on many ships. Spare lenses would be a necessity.

- Both inspectors expressed a concern about the apparent difficulty in changing bulbs in some of the more advanced xenon and halogen lights, and about easily obtaining spare bulb units for those which use non-standard bulbs.

Escape Lights

Most inspectors carry a small flashlight as an escape light should their regular light fail or get lost while they are in a dark space. Some inspectors at Newport News pointed out that a head-mounted light could double as an escape light. When inspecting tank vessels, inspectors generally wear their hardhats all the time. However, one of the inspectors interviewed at Erie said that he regularly leaves his hardhat behind when crawling double-bottoms of bulk-carriers, the situation in which an escape light is needed the most. A helmet-mounted light could obviously not double as an escape light in such a case.

Individual Flashlights

Pelican Super-Sabre

This light is used by many inspectors. One of the inspectors in Erie had tried one in the past, but he had problems with the lens-turn switch jamming in the on position. We experienced just such a problem with the Super Sabre light we brought. It had to be disassembled in a ballast tank to clear up the problem. Had any of the parts dropped through the grating to the mud on the lower level they would have been difficult to find.

The Sabrelight is very bright but the beam is very narrow (and is not adjustable). It is approved for hazardous locations.

Pelican Pro

This is a plastic-case xenon light which is free of many of the limitations discussed above. The batteries load from the rear without disturbing the bulb or reflector. The rear cap could easily be tethered to the body to prevent any loose parts during battery changes. The light has a conventional one-hand switch, and a spare bulb element is accessible by simply moving the switch to a different position. Its beam pattern is not adjustable and is much wider than that of the Sabre light - too wide for many applications. With an adjustable beam, this light might be an ideal inspectors' light. One inspector liked this light, the other didn't, principally because of the rather diffuse and non-adjustable beam pattern. It is approved for hazardous locations.

Kohler 8400-T

This light was the favorite of both inspectors at Erie. It is small, light, and bright. Its beam pattern, while not adjustable, offered a good compromise between the narrow beam of the Sabre light and the wide diffuse pattern of the Pelican Pro. It is necessary to disassemble it to replace the batteries, however, one of the inspectors felt that it was easier to replace the battteries in this light than in some other similar lights. It has a conventional on-off switch and can be operated with one hand - both

inspectors liked this feature. Both inspectors felt it was better than the lights they curently use. It is approved for hazardous locations

Underwater Kinetics Q-40

Both inspectors found this light to be very impressive for its size. It is very bright, even in comparison to full-sized flashlights, and is small and light. because of its brightness and small size, however, its battery life is not expected to be sufficient for it to be used as a primary light. One inspector felt that it would be a good escape light that would not only allow safe exit from a confined space, but would allow an inspector who lost his or her primary light to finish up the remaining inspection work before leaving the space. It is not approved for hazardous locations, although its construction is identical to many of the lights which are approved; it might be easy to obtain hazardous location approval for it.

Pelican Mity-Light

Both inspectors found this light to be smaller, lighter and brighter than their Mini Mag-Lite escape lights. It is approved for hazardous locations. However, lab tests have indicated that it tends to overheat if used continuously, and that it shuts off when overheated.

Streamlight Survivor

Neither of the inspectors at Erie thought that the Survivor would be useful for in bulk carrier inspections.

One inspector mentioned that he had heard good reports about the Makita rechargeable lights. These are available in 7.2V and 9.6V models and use the Makita one-hour fast charger and changeable Makita NiCad battery packs. These lights were not included in this test program.

**Hand Lanterns- General Observations**

The inspectors at Erie were less enthusiastic about hand lanterns, in general, than were the inspectors at Newport News. There are few occasions on which a bulk-carrier inspector needs to project a high level of light a great distance to evaluate structural components. The inspectors tried all the hand lanterns in a darkened cargo space on the larger of the two bulk carriers we visited, even though they would normally inspect this space with the hatches opened. The dimensions of this space were similar to that of a centerline tank on a VLCC. In general, they felt that the weight of the smaller (NiCad) battery pack was not objectionable. They preferred lights with on-off switches to trigger switches, even if the triggers had locking mechanisms. They were concerned about the effects of abrasive dust on the plastic lenses of many of the lights, and about

the ruggedness of the lightweight plastic plug-in lanterns. One inspector liked one of the heavier self-contained hand lanterns despite its considerable weight. In general, they were less concerned about the weight of lighting equipment than tankship inspectors at Newport New had been.

Individual Hand Lanterns

King Pelican

This is a self-contained light which uses four D-cells. One inspector who used this light found it to be bright, but the switch was difficult to use. The model tested had the dimpled diffuser-type reflector. It is also available with a smooth surfaced spotlight reflector.

Underwater Kinetics

This is a self-contained light which uses 8 D-cells. One inspector used this light extensively and liked it because of its bright beam and apparent durability, despite its rather high weight. this light also had a dimpled diffuser reflector, and it is also available with a spot reflector.

Night-Tracker RC-500K

This is a self-contained light which uses an internal NiCad rechargeable battery. It was by far the most powerful lightweight self-contained light tested and its intensity is equivalent to that of some of the 12V plug-in lights. Inspectors liked its beam pattern and brightness, but felt that its 30 minute battery life was too short for it to be really useful. The inspectors expressed concern about its durability.

Collins CD-12

This is the heaviest and brightest self-contained light. In spotlight mode its light output was similar to the two 1 million candlepower plug-in lights. Both inspectors considered it too heavy and cumbersome to use. It has a large base and a swiveling head and is the only light tested which was designed primarily to be set down on a surface and aimed, rather than held in carried. There are no suitable horizontal surfaces in a bulk carrier.

Q-Beam Max Million and LSI 1 million candlepower lights

These lights are essentially equivalent in brightness. Both inspectors preferred the slide switch of the Max Million to the locking trigger of the LSI light. The inspectors indicated that in an appropriate situation, they would carry the Max Million and a battery pack. They were concerned about the apparent lack of

durability of these lights and the susceptibility of the plastic lenses to scratching in dusty environments.

Specialty Mobile Patrol Light

The inspectors liked the durability and the glass lens of this light. However, the light output was not as great as the million-candlepower lights, and they disliked the non-locking trigger switch.

**Head-Mounted Lights**

Three types of head-mounted lights were tested, and both inspectors were encouraged to try all three. None of these lights are approved for use in hazardous locations, and all have integral batteries. Neither of the inspectors had previously used headlamps, and both felt that a headlamp would be a positive addition to their equipment.

Pelican Versa-Lite

This two-AA-cell light was generally liked by the inspectors, and preferred by one of the inspectors over the other two lights, principally because of its light weight. The elastic band which came with the Versa-Lite was found to be useless on a hard-hat, as it had been in previous tests. The light was used with a rubber strap from an REI headlamp, which mounted it securely to a hard-hat, but which appeared to overstress the side tabs of the Versa-Lite case. A small modification would correct this problem.

REI Headlamp

One inspector preferred this four-AA-cell headlamp because it was considerably brighter than the VersaLite. The other inspector felt that the weight upset the balance of his helmet. The rubber strap was excellent, and was found to be the best way to mount a VersaLite to a hard hat, as well.

TopSpot

One inspector tried and liked this four-AA-cell light because it was brighter than the other two headlamps and because it could also be used as a hand-held light. However, both inspectors agreed that it was not durable enough for sustained use in an inspection environment. The rubberized pads allowed it to mount securely on a hard hat.

**Binoculars and Monocular**

Both inspectors used the Unitron binoculars and monocular in dark cargo spaces, in combination with flashlights, hand lanterns, and 12V plug-in lights. Neither of them liked the monocular, but both liked the binoculars and said that if these binoculars were available

to them they could use them to advantage during inspections. They found that the binoculars were useful with the hand lanterns and with 12V plug-in lights, but that flashlights didn't provide enough light to make the binoculars useful.

**Night-Vision Equipment**

The inspectors tried both the night-vision monocular and the Night-Mariner night-vision binocular in a dark cargo space. While impressed with the technology, they didn't feel that either provided sufficient resolution to be useful for inspection purposes.

**Vests and Belt Packs**

One of the inspectors tried the fishing vest and found that the pockets were useful for carrying equipment. He said he would prefer coveralls with more and larger pockets built in to the vest, however. Both inspectors said that suitable coveralls are hard to obtain, and that 100% cotton is preferable, especially in hot weather.

Neither inspector liked belt packs, since they tend to inhibit movement when moving through double-bottoms. However, they both indicated that belt packs might be useful in other circumstances.

**Batteries**

One of the inspectors felt that there was a major difference between brands of standard D-cell alkaline batteries. He stated that his Mag-Lite gets 8 hrs on Energizer D-cell alkaline batteries, but only 2-3 hours on GSA alkalines. MSO Buffalo will not pay for non-GSA batteries for its inspectors, however. Perhaps tests should be done to investigate the claim of superiority for the Energizer batteries.

The inspectors knew an ABS surveyor who uses a Mag-Lite with a rechargeable battery pack made up of 3 cells shrink-wrapped together, and has good luck with this configuration.

**Combinations of Binoculars and Lights**

While inspecting the cargo space of the larger bulk carrier, several cracked welds were discovered between a transverse bulkhead and its stiffeners. These were found by an inspector while the area was illuminated by a high-intensity 12V plug-in light held by another person located off-axis from the inspector's angle of view. These failures wer then observed with several lights aimed from different angles, and with binoculars. Several rough conclusions were drawn from these observations.

- These failures could not have been seen by the inspector from that diatance (15-25') with a standard flashlight.

- The off-axis lighting helped to highlight the failures. Even using the high-intensity light, if the inspector aimed the light from his own position, the failures were not easily seen.

- Binoculars, in combination with high-intensity lighting made it easier for the inspector to evaluate the failures from a distance.

- Binoculars, in combination with the inspector's normal flashlight, did not allow the failures to be identified from a distance.

Both inspectors commented on the difficulty of simultaneously aiming a light and binoculars. This was clearly a two-hand operation, and could only be done from an area providing firm footing.

Trip Report

Ed McClave
MAR, Inc.
Evaluation of Innovative Inspection Techniques

**Trip to New Orleans LA March 21-24, 1994**

On March 21-24 1994 I accompanied Mr. Kurt Hansen of the R&D Center to New Orleans, La. in support of the "Evaluation of Innovative Inspection Techniques" project. The purpose of the trip was to accompany Coast Guard Inspectors on one or more inspections and to record their evaluations of equipment. The equipment which was provided by the R&D Center for this trip included flashlights, head-mounted lights, hand lanterns, one night-vision scope, and one multi-gas monitor, all of which had received favorable comments from inspectors in previous trips.

Three vessels were visited: a large manned derrick barge, which was hauled out in a floating drydock at Avondale Shipyard, a raised-deck double-bottom tank barge undergoing interior surface treatment and exterior repairs, also hauled out, and a double-bottom flush-deck asphalt barge which was in the water. We accompanied two inspectors from the MSO New Orleans West Bank Detachment, LCDR Dick Kulak and CWO Joe Grimes.

One potable water tank was and one stern ballast tank were entered on the derrick barge. The dimensions of the water tank were approximately: 16 ft. deep, 25 ft. wide, and 60 ft. long. The only access was by a manhole from the second deck in the forward accommodation area. The bottom, sideshell, and inside longitudinals were all exposed inside the tank, and recently completed repairs were obvious. The tank had not yet been cleaned for coating.

The ballast tank was deeper, extending to the main deck under the crane area, and it had one transverse web frame which divided the tank into two sections. The large hand lanterns, night-vision scope, and magnification equipment were evaluated in this tank. Recent repairs had been made to the bottom plating in this tank. This was the only space entered which could be considered a large space and in which lights stronger than standard flashlights would be useful.

One cargo space was entered on the tank barge. Since it was a double-hull barge, no internal structure other than a few underdeck transverse brackets were exposed inside the tank. The tank measured about 12 ft. deep, 25 feet wide, and 50 feet long, and it had just been blasted to bright metal.

One double-hull tank was entered on the asphalt barge. The space was only about 2.5 ft wide, and the space between the bottom of the cargo tank and the bottom of the barge was only about 2 ft. high. This tank had numerous recently repaired structural failures. The inspectors planned to return the next day for an official internal structural exam.

**The Inspection Environment**

The principal workload of the New Orleans office, in particular the West bank Detachment, is tank barges. The Coast Guard inspects all ocean-going barges, and any river barges which carry flammable or hazardous materials. The majority of the river barges have double-hull construction, which places virtually all of the important structural members except deck transverses in the confined double-hull spaces. Cargo spaces on barges are much smaller than those on tankships. These inspectors rarely need any high-intensity long-distance lighting equipment. Since the spaces they work in are small and they do not spend a long time in one space, they do not require long battery life either, except for convenience. Their requirements for lighting equipment were the least rigorous of any inspectors we have interviewed to date.

The double-hull tanks on barges contain virtually all of the important internal structural members on double-hull barges, and they are void spaces, not used for ballast or cargo. The environment is dark, dirty, rusty, and wet due to accumulated condensation. Access is through deck manholes at either end of the space. These spaces generally extend for 1/3 the length of the barge, and are continuous from side to side. However, the centerline girder has only small lightening holes, so the double-bottom space must be inspected separately from each side. Inspectors generally view the double-bottom space from the side, only crawling into the tight spaces enclosed by the adjacent floors, the bottom of the barge, and the tank bottom of the cargo tanks when it is absolutely necessary.

It was apparent that access openings on barges, including manholes, lightening holes in structural members, and double-bottom and double-side clearances, are minimally sized. Barge inspectors, therefore, prefer not to carry any equipment hanging from their bodies as this interferes with moving thru these access openings. In general, inspectors prefer to carry as little equipment as absolutely necessary when inspecting barges, and they that the equipment be small so as not to extend from their bodies.

**The Inspectors' Normal Equipment**

CWO Grimes's normal flashlight was a government-issue 3-D-cell intrinsically safe waterproof flashlight, which he found barely acceptable for close-up work. He complained that the switch was unreliable.

LCDR Kulak used a rechargeable hand lantern with a D-handle and a sealed-beam bulb. He was generally satisfied with this light for the work he does. We were not able to ascertain the manufacturer of this light. He said he got it from the Avondale Shipyard, and that people there also used and liked them.

**The Need for Equipment Approved for Hazardous Locations**

The New Orleans inspectors' comments were similar to those of other inspectors, that is, that they virtually never enter a space for inspection purposes in which there is a danger of

explosion, and therefore, they did not necessarily require that their normal lighting equipment be intrinsically safe. Inspectors investigating casualties might be more likely to encounter a situation requiring approved equipment, for example, a collision involving a gasoline barge, at night. MSO New Orleans does handle a fairly large volume of casualty investigations, and there are a lot of barges carrying hazardous liquids on the Mississippi. there is clearly a need for outside approved lighting at this office, but not a great need for approved lights for internal inspections.

**Gas-Monitoring Equipment**

The principal need of the New Orleans inspectors is for a reliable, easily carried oxygen monitor. They did not like the Neo-Tox units currently issued to inspection offices. They rarely enter a space in which explosive atmospheres might exist. The Industrial Scientific 3-gas monitor which we brought was somewhat large and bulky for inspectors working in and crawling through tight spaces. The inspectors did not mention any cases of $H_2S$ problems in their area.

**Flashlights - General Observations**

For inspectors who mainly work barges, a good, bright, easily carried flashlight is the most important piece of equipment. Both inspectors noted that lights which are small enough to be carried in a pocket should have both a pocket clip and an attachment point for a lanyard. It was suggested by one inspector that hand lanterns and longer flashlights like the 3-cell Mag-Lite or the Pelican Pro should have two attachment points for lanyards, one near the tail end and one near the lens or head. [A two-point lanyard would solve many of the potential "loose-parts" problems when changing batteries or bulbs.] LCDR Kulak felt that all flashlights should be colored yellow to make it easier to find them if dropped in a wet or muddy bilge.

Individual Flashlights

Pelican Super-Sabre (3-Cells, Approved)

Both inspectors liked the clip and lanyard arrangement on this light, but did not feel it offered superior light output, and did not like the two-hand lens-turn switch.

Pelican Pro (4-C, Approved)

CWO Grimes felt that this light was the best flashlight he tried, clearly preferred it to his regular light, and would carry it as his primary light. He thought it could use another lanyard attachment point near the head.

Mag-Lite (3-D, Not Approved)

Both inspectors liked the rugged construction of the Mag-Lite, but felt it was fairly heavy and that its beam was only bright enough for distant inspection when focused to the tightest spot setting. While inspectors in other ports had commented favorably on the Mag-Lite's adjustable beam pattern, the New Orleans inspectors did not find this to be a great advantage, probably because they generally do close-up inspections in barges.

Koehler 8400T (4-C, Approved)

Both inspectors liked the intense light output and the simple light construction of this light. They rated it near the favorite, the Pelican Pro, as a general inspection light. The one-hand switch was considered to be a good feature of this light.

Underwater Kinetics Q-40 (4-AA, Not Approved)

Both inspectors felt that this light would make an excellent escape light and tight-location inspection light. They both thought it should have a pocket clip like the smaller Pelican lights have.

Pelican MityLite (2-AA, Approved)

CWO Grimes liked this light as an escape light. Both inspectors liked the pocket clip.

Escape Lights

Neither inspector apparently carried an escape light regularly, probably since one is rarely out of sight of a deck opening when inspecting barges, but both of them liked the idea of a very small escape light. They both liked the Pelican Mity-Lite and the Underwater Kinetics Q-40. Both preferred the Q-40 because of its high light output, but felt it needed a pocket clip like that of the Mity-Lite or the Super-Sabre. LCDR Kulak felt that a Versa-Lite would also make a good escape light, either when used as a head-mounted light or clipped in a pocket.

**Head-Mounted Lights**

Neither inspector had used head-mounted lights. Both inspectors tried both the REI and Pelican Versa-Lite. They both found the head-mounted lights to be useful, and both preferred the Versa-Lite to the REI light, despite the higher light output of the REI unit. The Versa-Lites were mounted on the inspectors' hard hats with duct tape in one case, and with an REI headlight band in the other case.

**Hand Lanterns**

Both inspectors liked the light output of the self-contained hand lanterns - the UK 1200, the Pelican Brite-Lite, and the NiteTracker RC 500. However, both commented unfavorably on the pistol-grip handle arrangements which these lights used. They felt that the UK 1200 was too heavy to be carried continuously. Their recommendations for hand lanterns can be summed up as follows:

Not as heavy as a UK 1200
Two attachment points for lanyard
Simple non-momentary switch
Case which prevents rolling when set down
Provision for aiming when set down
D-handle rather than pistol-grip

[Observations of the UK 1200 and the Pelican BriteLite indicate that large lens diameters do not necessarily provide higher light output - the UK 1200 is brighter, but smaller in diameter than the Brite-Lite. Large lens diameter does make carrying and handling more difficult.]

CWO Grimes pointed out (and demonstrated) that the Pelican Pro flashlight projected as much light as the BriteLite, despite its smaller size and lower weight.

The Collins CD-12 was demonstrated in the office, but was not taken to any vessels, as it was felt that the spaces to be inspected were not large enough to warrant a light of this size. The inspectors had no strong opinions about whether it would be useful during a tankship inspection. It has been noted in past field trials that inspectors who do not think that a particular type of light (particularly large, bright lights), will be useful when they first see it are often more enthusiastic when they actually use these lights in a large dark space.

**12V Battery-Pack Lights**

We brought several of these lights with us, but did not bring any to the barges because we did not anticipate being able to use them in any large spaces.

**Binoculars**

Two magnification devices were tested, the Unitron mini-binoculars and a Unitrom monocular. The binoculars, which had been found very useful on previous field trials, had apparently become misaligned, and in this condition they were more or less useless. During previous field trials, these binoculars have been subjected to exactly the type of handling which they would be expected to encounter in an inspection environment, and a few hours of this handling have resulted in a great degradation in performance. It is clear that for them to be useful, they must either be made more resistant to minor impact and moderately rough handling, or some easily used and non-bulky protective carrying system must be devised. The padded case which the binoculars come with is more of a dust cover than a physical protective case.

The monocular provided a good image and was very compact and light. The necessity to focus it was a disadvantage - a fixed focus monocular might be better suited to the task (the Unitron binocular is a fixed-focus device). Both inspectors found the use of a monocular awkward and unnatural compared to a binocular - the necessary squinting of one eye while using it is uncomfortable. [It is possible that after using a monocular for a while, one might become accustomed to it - in our trials nobody has ever used it for more than a minute or so]. The problems encountered with the binocular pointed out one obvious advantage of a monocular - it cannot lose its alignment due to rough handling, since there is only one set of optics.

**Night-Vision Equipment**

The only night-vision equipment used in these tests was the single-tube U.S.-made non-magnifying night vision scope which had been found to be most effective on previous trials. Neither inspector found this device to be useful. The double focus arrangement is particularly troublesome when attempting to scan a large area, since even a slight change of target distance requires two iterative focus adjustments.

**Inspection Hammers**

Both inspectors complained that the standard USCG inspection hammers are inadequate - the handles fall off too easily. I looked at one of the hammers, and it appeared that the hole for the handle tapered too sharply from the bottom to the top of the head, allowing the handle to work loose under vibration despite being wedged.

**A Need for Remote Inspection Equipment**

Two cases in which remote inspection equipment would be helpful to inspectors were brought to light during the visit to New Orleans: inspections of ballast tanks on chemical-carrying vessels, and inspections of air receivers and other permanently installed cylindrical pressure vessels.

<u>Ballast Tank Inspections</u>

Marine Inspection regulations require inspectors to enter ballast tanks on tankships and tank barges. In many cases these tanks contain important structural components, and the corrosion environment in ballast tanks is generally severe, meaning that the worst degradation of structure often occurs there.

However, there have been a number of safety problems on chemical tankships and chemical barges resulting from leakage of chemicals from cargo spaces into adjacent ballast tanks. This leakage often results from corrosion penetration of bulkheads separating ballast spaces from cargo spaces, thus the vessels most likely to have chemical leakage into their cargo tanks are also the most likely to have serious structural degradation in their ballast tanks. These problems have been frequent enough that several Officers in Charge of Marine Inspection (OCMIs) have instructed

their inspectors, in certain cases, not to enter ballast tanks which are adjacent to chemical cargo tanks despite the ballast tanks being a structurally critical area.

This is a clear case in which some form of remote inspection equipment, either a video-equipped Remotely Operated Vehicle (ROV) or Autonomous Underwater Vehicle (AUV) operating in a flooded ballast tank or a hatch-mounted remote video system in an empty tank, might be useful. Previous interviews with inspectors have indicated that they consider remote inspections of tanks to be clearly less effective and more time-consuming than entry of the tanks. However, in the chemical tanker case, a remote inspection may sometimes be the only reasonable approach and it is clearly better than no inspection at all.

Air Receiver Inspections

Marine Inspectors are required to perform periodic internal examinations of all pressure vessels. Most ships have numerous air receivers which fall into this category. These air receivers are cylinders varying in size from a few cubic feet to a hundred or more cubic feet. Access to the inside of air receivers is generally limited to one or more pipe connections which range from as small as 3/4" on small sizes to only a few inches in diameter even on large ones.

Inspectors presently use a flashlight and mirrors to conduct internal inspections of these pressure vessels, but they are not satisfied with the effectiveness of this technique. It is difficult for them to coordinate the aiming of the light and mirror to ensure that the small area illuminated is the same area being viewed. It is also difficult to manipulate both a light and a mirror simultaneously in the small openings provided. In many cases the only available openings are near the ends of long cylinders, making it very difficult to evaluate the internal condition at the far end.

Some inspectors have tried fiber-optic borescopes and report encouraging results, but the particular devices used often had insufficient reach to enable inspection of the entire inside of the cylinder.

There are at least several possible approaches to this problem:

1. Provide an intense floodlight powerful enough to illuminate the entire inside of the cylinder at one time. The light would have to fit through the small opening and have a small enough cord and supporting rod or stalk so as not to interfere with the inspector's inspection mirror. This would eliminate the problem of coordinating the aiming of a light and mirror - anywhere the mirror was aimed would be illuminated. However, inspection of remote areas of the cylinder would still be difficult because of a lack of magnification.

2. Use an optical device, such as a fiber optic scope or a video camera. The lighting would either be provided by a separate floodlight as suggested above or coordinated spotlight integral with the viewing device. Such a viewing device would either have to have zoom magnification capability or would have be able to be physically manipulated into close physical proximity to the area to be inspected.

3. Supplement the current simple cursory visual inspection with nondestructive test procedures which could be conducted from the outside of the tank. Ultrasonic thickness-gauging or acoustic emission tests for microcracks are among the possible approaches.

Trip Report

Ed McClave
MAR, Inc.
Evaluation of Innovative Inspection Techniques

**Trip to Portland, OR, April 25-29, 1994**

On April 25-29, 1994 I accompanied Mr. Kurt Hansen of the Coast Guard R&D Center to Portland OR in support of the "Evaluation of Innovative Inspection Techniques" project. The purpose of the trip was to accompany Coast Guard Inspectors on inspections of tank vessels and to record their evaluations of equipment. The equipment which was provided by the R&D Center for this trip included flashlights, head-mounted lights, hand lanterns, portable spot/floodlights, 12V battery-pack spotlights, night-vision binoculars, and multi-gas monitors; all of which had received favorable comments from inspectors during previous field tests.

In the course of three working days we accompanied inspectors on visits to a ferryboat under construction, a laid-up crude oil carrier, and a drydocked refined product tank vessel.

**Inspection procedures in Portland**

Most inspections of deep-draft vessels done from the Portland office are conducted either in the Portland Ship Repair Yard or in berths in the immediate vicinity. MSO Portland has an branch office in the shipyard, from which five inspectors operate. These inspectors do most of the deep-draft inspection work. Inspectors from the main office handle most inspections of ferryboats, T-boats, and other smaller vessels.

Many inspections are conducted in the yard on vessels undergoing repair or drydocking, and the inspectors generally stretch these inspections over the available time. This allows them to see more of the vessel than would be accessible in one or two-day inspection in a non-shipyard environment. Since the inspectors generally return to the office during the day, they do not often spend more than a few hours on board the ship at one time, and their need for lighting equipment with long battery life is limited.

The Portland Inspectors have some experience with rafting. The cargo tanks of a typical 165,000 dwt. ton tankship are rafted at three levels.

**Inspection Environments**

Crude carrier cargo spaces are large, dark, and nonreflective, and place the greatest demands on lighting equipment. Access to the tank bottoms is provided by inclined ladders with handrails, one per tank, leading from ullage openings on deck to the bottom of the tank, with several landings. In wing tanks, inspectors can only move around on the bottoms of the tanks. Some center tanks (not the one we were in) have stringer platforms at several levels, which may be

accessible by ladders. Close-up inspection of the upper sideshell or bulkheads and related internal structural components and of the underdeck structure is not possible without staging or rafting. The spaces may be very dirty and surfaces are coated with black paraffin and asphalt, but are not wet. There is typically very little corrosion in the lower levels of cargo tanks, where the coating of oil residue acts as a preservative, but there often is corrosion damage in the less accessible upper levels.

Ballast tanks and double-bottom spaces allow close-up access to all of the bottom shell, sideshell, tank bottom, and related internal structural components. Headroom is often limited, and the spaces are divided into many small cells by longitudinals and transverses. Double-bottom spaces extend across the entire width of the ship, and share the same transverse bulkhead arrangement as the cargo space. Thus, a vessel with 18 cargo tanks (6 rows, 3 across) will have 6 double-bottom spaces. Inspectors must move from one cell to another by crawling through access openings barely large enough to pass through. Carrying any heavy equipment or items hanging from the body is very difficult in this environment. These spaces may be wet and slippery, and surfaces may be covered with wet rust and mud. Intense lighting is not needed, since there is easy physical access to all of the structure in these spaces.

Access to double-bottoms is through deep trunks containing single vertical ladders from the main deck, which somewhat restricts the amount of equipment which can be carried. The double-bottom trunk we used had many electrical wires, welding leads, and air hoses in it in support of work which was in progress in the double-bottom. This equipment interfered seriously with safe climbing, and would have been a serious obstruction to anyone carrying a large piece of equipment, backpack, or other equipment hanging from the body.

Ballast tanks are entered through oval manhole openings on deck, and the open vertical ladders leading to the various levels require passage through manholes at each level. These openings would make it difficult to carry any large equipment. The ballast tank we entered (a forepeak tank) was very deep, had many levels, and was wet, muddy, and slippery.

Void spaces in the new-construction ferry required a number of entries through main-deck manholes, down open vertical ladders, into odd-shaped spaces. Many of these spaces had less than standing headroom and no horizontal surfaces on which to stand. Most inspection is done by climbing and crawling, which limits the equipment which can be carried. Intense lighting is not necessary, since most components to be inspected can be closely approached.

**The Portland Inspectors' Present Lighting Equipment**

Most of the Portland inspectors use rechargeable MagLites, which have NiCad batteries. These are similar to the 3-cell standard MagLite in size and weight, but they are much brighter. They use a high-wattage halogen bulb (the standard MagLites use standard or Krypton bulbs - halogen bulbs are advertised to be about 50% brighter than krypton bulbs for the same wattage). The inspectors estimate the battery life of the rechargeable MagLite to be about 1.5 hours. These lights are a single unit, and batteries cannot be easily swapped, thus, the entire unit must be recharged in a fairly large charging unit. The inspectors generally like these lights; their only

complaint is a problem with the bulbs. The two-pin halogen bulbs are held in their sockets by friction only, and tend to fall out if the light is dropped or otherwise hit. It is difficult to replace the bulb while in a tank.

The rechargeable MagLites are well-suited to the way inspections are done from the Portland shipyard office. However, the relatively short battery life and the unavailability of multiple battery packs would limit the usefulness of these lights in a situation requiring a full day of lighting. One Portland inspector estimated that during a normal full day of inspections an inspector needs 3 hours of actual illumination time, which is approximately twice what is available from a single rechargeable MagLite. This figure of 3 hours may be a good starting point for establishing a general battery life requirement for inspectors' flashlights. The Portland inspectors presently use MagLites during rafting inspections.

**Initial Impressions**

On our day of arrival, the inspectors looked over the equipment and tested some of it in a large dark room adjacent to the office. The inspectors had several comments about individual items or about general use of lights.

They thought that they would carry a monocular or binoculars on some inspections, and would also carry large lights (larger, heavier, and brighter than normal flashlights) in order to make use of magnification devices. They liked the UK Q40 as an escape light or as a main light to be used in conjunction with a large light or hand lantern.

**Visit to Ferry**

On Apr. 26 we accompanied one inspector and one shipyard representative on an inspection visit to a small auto/passenger ferry under construction in a slipway at the Nichols shipyard in Portland. MSO Portland is conducting weekly (soon to be semi-weekly) inspections to monitor construction progress. We entered most of the vessel's void spaces and weather-deck enclosures. Only small flashlights were tested on this inspection.

Flashlights

There are no requirements for lighting at great distances on a job of this type. The inspector used a rechargeable Mag-Lite, which seemed a bit large and heavy for this application. We tested the Koehler 8400T and UK Q40 flashlights. These offered similar illumination to the MagLite in the relatively tight quarters in the ferry. The Koehler and UK lights, being smaller and lighter, seemed better suited to this environment than did the MagLite, and offered much more illumination than the 6V lantern which the yard representative used.

Many inspectors and shipyard personnel carry their lights (6V lanterns or MagLites) on a lanyard which attaches to the light in two places and allows it to be slung over the shoulder and carried hands-free.

The inspector pointed out that flashlights are often useful in areas which might seem to be well lit already. He used his flashlight while inspecting welds on the overheads of deck enclosures and open but covered weather deck areas. The Koehler 8400T appeared to be a good light for this, since it was easier to handle than the large MagLite.

**Visit to Product Carrier**

On Apr. 28 we visited the *Delaware Trader*, a refined product tankship, which had been drydocked on a floating drydock the previous night. We accompanied two inspectors and one ship's officer into one double-bottom space and into the forepeak ballast tank. In the double-bottom, the inspectors carried only their flashlights and hammers. We also walked the bottom of the vessel in drydock.

Flashlights

The inspectors' MagLites appeared to be unnecessarily large for this application, in which all inspection took place at arm's length. One inspector used a Mag-Lite and the other used the Pelican Pro. The Koehler 8400T and the UK Q40 appeared to be equally useful in these tight quarters, since they could easily be placed in a pocket when crawling through access holes.

One inspector also used the Pelican Pro while inspecting the sea chests of this vessel in drydock, but did not comment on its performance. Despite the outdoor environment, lights are necessary when walking the bottom in drydock. The inspectors MagLites, the Koehler 8400T, and the Pelican Pro all appeared to be good for this purpose.

Head-Mounted Lights

Both inspectors used the Versa-Lites on mounted on their hard hats, and they both found them useful for navigating through the tight quarters. The inspectors did not appear to take any notes while in the double-bottom or ballast tanks, so there was no evaluation of the headlights as writing aids.

**Visit to Crude Carrier**

On Apr. 27 we visited a crude oil carrier, the *Overseas New York*, which is a *San Clemente* class double-bottom tanker, approx. 90,000 dwt. tons, built in 1977. This ship has 6 sets of cargo tanks (18 total). The six double-bottom spaces, 6 feet deep, extend across the ship. The ship was berthed at a pier in Portland. We entered one wing cargo tank and one center cargo tank, accompanied by two inspectors and the vessel's chief mate. In both tanks we walked the bottom only. The only physical access to the upper areas of the tanks is from the ladder, from which only a small portion of the upper structure can be seen, especially in the wing tanks, where the web frames obscure the view fore and aft.

One inspector would normally inspect a vessel of this size and type alone, spending about 1 hour in each accessible cargo space and double-bottom space. The entire internal examination

would take about 3 days if all spaces were accessible (double-bottom spaces are used for segregated ballast and might not be empty if a ship was in the water.

The ladder into the center tank on this ship was against a bulkhead and was quite narrow, which made it difficult to carry lights which extended sideways from the body.

Flashlights

The inspectors normally use their MagLites in this situation; these lights, even when focused to a small spot, did not appear to adequately illuminate the upper parts of the tanks. In such a situation inspectors would normally require the vessel or yard to provide floodlighting. We tested all of the small flashlights. In the tank environment, the Pelican Pro and Koehler 8400T were more or less equivalent to the inspectors' MagLites. The Super Sabre is bright, but the beam is very narrow, making inspection of large areas difficult. Flashlights are barely adequate in a wing tank, and are less than adequate in a center tank, where the only visible structural members are under the deck. The UK Q40, although too small to be an effective primary inspection light in cargo tanks, appeared to be an ideal secondary or escape light.

One inspector thought that the Koehler 8400T, while not powerful enough in a cargo tank would be ideal for double-bottoms, and for general up-close inspection work.

One inspector pointed out that lights which use lens-turn switching often fail to work properly after a fairly short time. We have encountered this problem with a Sabre-Lite and with a UK Q40 during other field trials, and have heard the same complaint from inspectors in other ports about the Sabre Lite.

Portable Spot-Floodlights

Both the Collins CD-12 and the TopLite were tested. Both are difficult to carry when descending and ascending ladders. If either was to be used frequently, some thought would have to be given to better carrying arrangements.

The TopLite was judged to be too heavy and awkward to carry, and difficult to use otherwise, since the beam is fixed to the case and thus it cannot be set down and aimed. It would be more useful as a portable deck floodlight for emergencies. The high-power spot setting is selectable only with a momentary switch, further decreasing its usefulness in a tank.

The Collins CD-12 spot/floodlight appeared to be the most useful large light. While it is too large and heavy to be carried continuously, it projects more light than any other light we tested, including the 12V battery-pack lights. It can be set down on a horizontal surface and aimed, leaving the inspector unencumbered. Its flood setting gives good overall illumination in a large space, but the flood intensity is not sufficient for inspection purposes. The spot setting lights up a larger area at high intensity than any other light tested.

The ship's chief mate thought that this light would be very useful and convenient for illuminating minor work in various internal and weather-deck spaces aboard ship, especially when the location of the work changes frequently. Cord-powered fixed lights are presently used in these situations.

Hand Lanterns

Inspectors tried the UK 1200, the Pelican Brite-Lite, and the Nite-Tracker RC500 in cargo tanks.

Underwater Kinetics UK 1200

Both inspectors liked the light output and beam pattern of the UK1200 but thought the weight would be a problem if it were carried all day. The optional D-handle configuration (not tested) would make carrying somewhat easier than the pistol-grip handle on the unit we had. As with other lights, a carrying harness with two attachment points is needed.

Pelican Brite-Lite

The inspectors did not particularly like the Brite-Lite.

Nite-Tracker RC500

The Nite-Tracker RC 500 is nearly as bright as the Max Million, and very light for a high-powered self-contained light, but its short battery life and the necessity to recharge it render it unusable for all but a short tank visit. (In a situation like that in Portland, where inspectors often run out of the office to look at only one space at a time on a vessel in the yard, this light might be of some use). As with other lights, inspectors prefer the slide-switch like that of the Max Million to locking and non-locking trigger switches.

12V Battery-Pack Lights

The battery pack lights were tested in one wing tank and one center tank of the crude carrier Overseas New York. Portland inspectors had previously used a Maxa-Beam portable searchlight with an integral battery case. Our Maxa-Beam unit, which uses a belt battery pack, was lost in shipping and was not available for testing in Portland. The inspectors who had used the Maxa-Beam had positive comments about it.

Brinkmann Max Million

Of the 12V battery-pack lights, the Max Million was judged to be the best by the inspectors because of its light weight, high intensity, good beam pattern, and convenient switch. (Inspectors, in general, do not like lights with momentary switches). One inspector felt that such a light would be used frequently in Portland if it was available. Inspectors were concerned about its apparent

lack of durability. One inspector thought that it was the only light tested which offered a clear improvement over the MagLite for inspections of large spaces.

Inspectors were interested enough in this light to suggest improvements:

A better plug (this problem is common to all lights with cigarette-lighter plugs). The plug pulls out of the battery pack socket too easily. [Most of the lights and battery packs are available with, or could easily be adapted to, a marine two-prong 12VDC plug, which would be less likely to come unplugged accidentally].

Better carrying system. The light needs a strap or harness which allows the inspector to let go of the light without it falling to the ground. Some kind of shoulder strap with a flexible strap would allow the light to be carried close to the body, leaving the inspector's hands free, but allow it to be aimed and used quickly.

One inspector thought that a spot/flood capability would be desirable. The Blue-Max light, which we did not test here, does have a spot-flood bulb but its output on the spot setting is lower than that of the Max Million, and its spot beam pattern is not as clean as that of the Max Million.

Specialty Lighting Mobile Patrol Light

This light is also nearly as bright as the Max Million. The principal objection inspectors had to it was the non-locking trigger switch. It is somewhat smaller, a bit heavier, and appears to be considerably more durable than the Max Million. With a better switch and carrying system, this light might, in the long-term, make a better inspection light than the Max-Million due to its durability.

The inspectors who tried the battery-pack lights in the crude carrier said that this type of light would be useful during rafting inspections.

Head-Mounted Lights

All of the five inspectors in the Portland shipyard office were encouraged to try head-mounted lights and most of them used them in more than one situation during the week of the tests. By the end of the week, the Versa-Lite had emerged as the clear favorite. One inspector tried the Top-Spot and initially he liked it because it was more powerful than the other headlights and its beam could be focused. He felt that in tight quarters it might be usable as a primary inspection light instead of a hand-held flashlight. However, after using it for several hours, he decided that it was too heavy and too unbalanced to be used comfortably. Other inspectors thought it was not durable enough. The four individual battery compartments with untethered covers would make changing batteries dificult, and the covers could be dropped and lost very easily.

REI Headlamp

Several inspectors tried the REI Headlamp, and also felt it was too heavy and unbalanced.

Pelican Versa-Lite

Everybody who used the Versa-Lite liked it, however, some modifications were necessary in every case to mount this light on the inspectors' hard hats. The elastic headband supplied with the light needed to be taped to a hard-hat to prevent it from slipping off. The REI rubber headband also worked well for mounting the VersaLite, but the tabs on the side of the VersaLite are not designed for and might not stand the stress imposed by the rubber headband over a long time period.

Magnification Devices

The only magnification device which was tested was the Unitron 8x25 monocular. This was used in the wing and center tanks of the crude carrier. Inspectors indicated that the combination of a magnification device and a high-powered light had potential, but it was clearly a major change from their normal practice. For this combination to get a fair evaluation, it would be desirable for some inspectors to use it for some time.

Using the monocular and powerful portable lights, inspectors could definitely see details in the high areas of large tanks which would not be visible to the unaided eye from the tank bottom. The monocular was tried with the Collins CD-12, and with the Max Million light (one inspector holding the light, one looking through the monocular.

One inspector tried attaching the monocular to a light to solve the problem of simultaneous aiming; this experiment was inconclusive. The inspectors felt that the image was jittery, and that the field of view was small. They also had trouble maintaining balance when looking through the monocular. This was not a problem on the flat floor of a tank in a double-bottom ship, but it would be a problem in a single-hull vessel, where there are only narrow perches available. The binoculars which were tested in previous trips were not available. The jittery image and narrow field of view are related to the magnification, which, at 8 power, is at the high end for a low-mass hand-held device. A 6 or 7 power monocular would eliminate some of the jitter and would also provide a slightly wider field of view. Binoculars might be easier and less fatiguing to use than the monocular, and keeping balance is somewhat easier when using binoculars than when using a monocular.

One inspector suggested attaching a magnification device (a small monocular or binocular) to a hard-hat so it could be flipped down when needed.

Night Vision

The ITT Night Mariner night-vision binoculars were tested in the cargo spaces of the Overseas New York. They proved to be no more effective than the combination of a bright

flashlight and the naked eye, and are considerably less effective than a standard magnification device used with a high-powered light.

**General Observations**

Inspectors felt that virtually every light tested lacked adequate provisions for carrying it. To be useful in the inspection environment, a light needs a specialized carrying arrangement which is designed for both the particular light and for the unique conditions encountered in vessel inspection.

**Video Inspection**

Two of the Portland inspectors witnessed a commercial survey of a the Trans-Alaska Pipeline Service (TAPS) tankship *Prince William Sound*, owned by the Keystone Shipping Company, conducted in Aug. '93, in which remote video equipment was used. The survey was conducted by Ronald Nisbet Associates of Portland, a well-known commercial marine surveying firm. The Coast Guard inspection of the vessel coincided with this survey. Nisbet had subcontracted a firm named NETS to perform inspections of the underdeck structure of all the cargo tanks on this vessel using video equipment.

The NETS system was a video-light system designed to fit in a Butterworth opening, rotated manually and panned and zoomed remotely, and viewed with an above-deck monitor. NETS conducted the underdeck portion of the survey while Nisbet surveyed the sides and bottoms of the cargo spaces. Two NETS technicians took three days to inspect the entire underdeck structure, and found a few fractures. The CG inspectors are not sure how qualified or experienced the NETS technicians are as surveyors, or if they found all of the failures in the area they surveyed.

Inspectors suggested contacting Keystone Shipping's port engineer for more information about the video survey.

NETS contact point:

Les Beneke
Port Engineer
Keystone Shipping
Wilmington CA 90744
310-549-8780
310-830-3658 FAX

Trip Report

Ed McClave
MAR, Inc.
Evaluation of Innovative Inspection Techniques

**Trip to New York May 12, 1994**

On May 12, 1994 I accompanied Mr. Kurt Hansen of the Coast Guard R&D Center to the Coast Guard Marine Inspection Office in New York in support of the "Evaluation of Innovative Inspection Techniques" project. The purpose of the trip was to demonstrate equipment to Coast Guard Inspectors which might have the potential of improving the accuracy and efficiency of inspections. The equipment was shown to the inspectors in the office, they were briefed on its use, and they were allowed to select items which they felt might be useful in the type of inspections they do. Equipment selected by the inspectors was left with them for further evaluation in the field. We did not accompany any inspectors on visits to vessels.

The equipment included flashlights, head-mounted lights, hand lanterns, portable spot/floodlights, 12V battery-pack spotlights, binoculars and monoculars, and multi-gas monitors, all of which had received favorable comments from inspectors during previous field tests.

The Coast Guard Marine Investigation group in New York operates out of the same facility as the Marine Inspection Office, and representatives of this group were present at the equipment briefing.

**Inspection Procedures in New York**

The New York office is very large - there are about fifty working inspectors, in addition to administrative and office personnel. They inspect a large number of seagoing barges and small passenger vessels. New York inspectors also inspect many tank vessels, but almost all of these inspections are conducted overseas. Inspectors from New York cover Europe, Africa, and the Persian Gulf area. The travel circumstances associated with their deep-draft vessel inspections greatly limit the amount and size of the equipment they can carry with them on these inspections.

<u>Present Equipment</u>

Many of the New York inspectors use standard GSA 3-D-cell approved flashlights as their standard inspection lights. Of all the offices visited so far in this study, New York seems to have had less exposure to the more advanced technologies in portable lighting equipment than the others. This is apparently due to the type of lights which the inspection office supplies as standard equipment. Some other offices supply the Pelican Super Sabre-Lites to their inspectors; Portland supplies the rechargeable, halogen Mag-Lites, etc. New York, possibly because of budget limitations and the large number of inspectors, supplies the standard 3-cell GSA light.

The New York inspectors have not had much experience with head-mounted lights, with self-contained portable spot-floodlights, used with or without magnification equipment, or with 12V battery-pack lights. They offered to test equipment in all of these categories.

The Need for Approved Equipment

As with inspectors from other offices, New York inspectors rarely enter closed spaces which are not safe for hot work, that is, spaces in which equipment approved for use in hazardous locations is required. As a result, high-intensity lighting equipment which is primarily intended for use in inspecting cargo tanks does not really need to be approved.

The place where inspectors do need approved equipment is when walking the deck of tank vessels which are carrying cargo. This situation arises primarily during safety inspections of foreign tank vessels entering U.S. waters and during investigations of casualties involving tank vessels or tank barges. Since deck inspections of tank vessels generally occur during daylight, lights are usually not necessary. For casualties, however, approved lights are often necessary.

**Equipment Left for Evaluation**

The equipment which the inspectors decided to keep and test included the various head-mounted lights (Pelican Versa-Lite, REI Headlamp, and the Top-Spot convertible light). They kept several types of flashlights, the Pelican Mity-Lite, Super-Sabre, and the Pelican Pro, the Koehler 8400T, and the UK Q-40, along with several Mag-Lites.

The UK 1200 hand lantern was found to have a broken switch when it arrived at New York - this may be a characteristic weakness of this light which indicates a need for redesign. A replacement for this light will be sent to New York, and the inspectors will test both this light and the Pelican Brite-Lite in the hand lantern category.

One pair of 7x25 binoculars and an 8x25 monocular were left at New York for use in conjunction with high-intensity lights.

In the self-contained portable spot-floodlight category, the Top-Lite (approved for hazardous locations) and the Collins CD-12 (not approved) were left with the New York inspectors for evaluation. The Brinkmann Max-Million and the Specialty mobile Patrol Light were left, along with the small NiCad battery packs (Neither of these lights is approved).

The Industrial Scientific multi-gas meters were also left for evaluation.

**Initial Comments**

Inspectors were shown the various fishing vests and belts intended for carrying equipment. Most inspectors prefer not to wear anything outside their coveralls or hanging from the waist, since hanging objects can interfere greatly with climbing through manholes and other small access openings, especially in barges and double bottoms. some inspectors have suggested that

specialized coveralls with pockets designed specifically for the equipment which inspectors need to carry, would be preferable to carrying gear hanging on the outside of the coveralls.

One inspector in New York had obviously given the subject of carrying inspection gear some thought. He did not like the idea of a separate fishing vest worn on the outside of the coveralls since, feeling that the one-piece smooth surface of coveralls is an advantage in climbing through tight openings that should not be compromised by wearing equipment or other garments on the outside. He felt that a vest-type carrying garment which actually zipped onto the coveralls, leaving no exposed or hanging edges, would be best. This vest could be easily removed and left behind when access to an extremely tight space was necessary. In addition, several different types of zip-on vests could be used with the same basic coveralls in different inspection environments. Of the many ideas proposed by inspectors for improving their ability to carry equipment with minimal limitations on mobility, this is one of the best, and merits further consideration.

Several inspectors commented on the potential difficulty of using rechargeable equipment, especially overseas where the charging equipment may not be compatible with the available electrical connections, or where charging connections may not be available. The multi-gas monitor, which has a relatively short battery life for this type of device, and a fairly long charging time, could be particularly troublesome in an overseas situation, especially if a number of inspections were being made on successive days.

Inspectors made a number of initial comments about carrying provision for lighting equipment. Virtually all of the lights, from the smallest flashlights to the large self-contained spot/floodlights, lack proper attachment points for carrying lanyards or straps. The larger lights that do have straps are still difficult to carry when descending ladders, and the strap systems need to be redesigned.